PROJECTS ■ THEORY ■ APPLICATIONS ■ CIRCUITS ■ TECHNOLOGY

NUTS AND VOLTS

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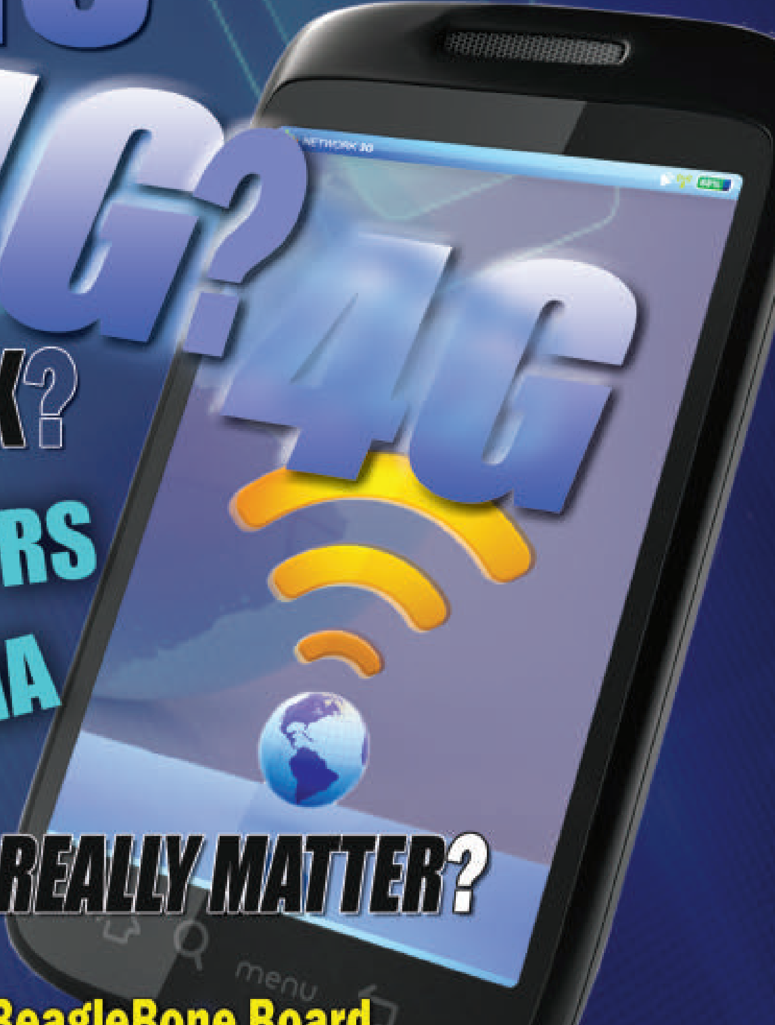
June 2012

EVERYTHING FOR ELECTRONICS

WHAT IS 4G?

DO I NEED IT?
DO I CARE?
HOW DOES IT WORK?


UMTS
GSM
LTE
4G
WiMAX
OFDM
EDGE
GPRS
HSPA
EV-DO
CDMA
NETWORK 3G
menu

3G/4G ... *DOES IT REALLY MATTER?*

- ✦ Crack PDF File Passwords With A BeagleBone Board
- ✦ Turn Your iPhone Into A Plant Soil Moisture Sensor
- ✦ FUNdamentals For Beginners
Build A Morse Code Oscillator

U.S. $6.50 CANADA $7.50
06
0 71486 02421 7

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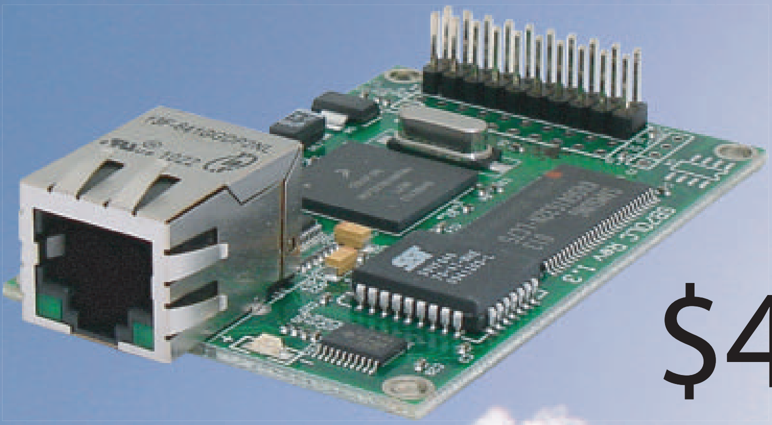

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- SSH/SSL Option
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- Example applications

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SB70LC Development Kit

The SB70LC Development Kit

The NetBurner SB70 LC Development Kit is available to customize any aspect of operation including web pages, data filtering, or custom network applications. The kit includes platform hardware, ANSI C/C++ compiler, TCP/IP stack, web server, e-mail protocols, RTOS, flash file system, Eclipse IDE, debugger, and cables. The kit enables you to communicate with peripherals that use SD/MMC Flash Card (including SDHC), SPI, I²C, or the general purpose digital I/O interface. The NetBurner security suite option includes SSH v1, v2 and SSL support.

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Development Kit Part Number | NNDK-SB70LC-KIT
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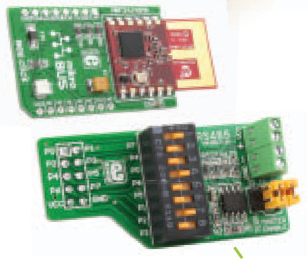

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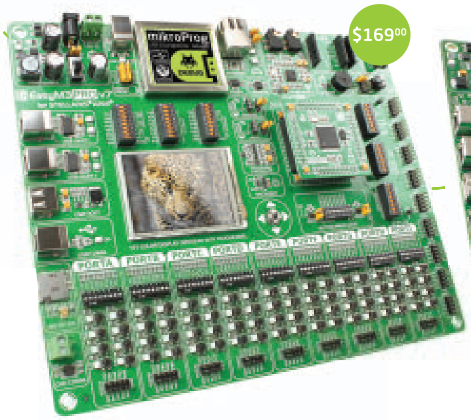

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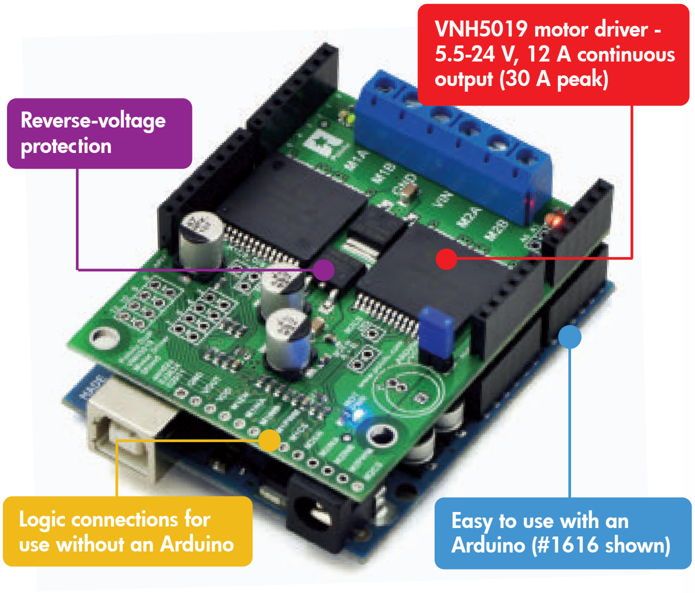
Motor Drivers:

Item #2502: Dual VNH5019 Motor Driver Shield for Arduino



VNH5019 motor driver - 5.5-24 V, 12 A continuous output (30 A peak)

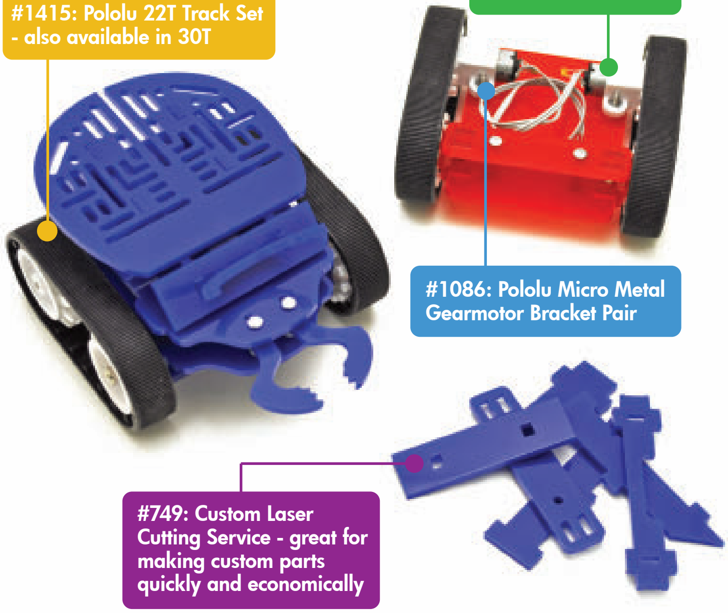
Reverse-voltage protection

Logic connections for use without an Arduino

Easy to use with an Arduino (#1616 shown)

Custom Laser Cutting:

Design Your Own Chassis



#1415: Pololu 22T Track Set - also available in 30T

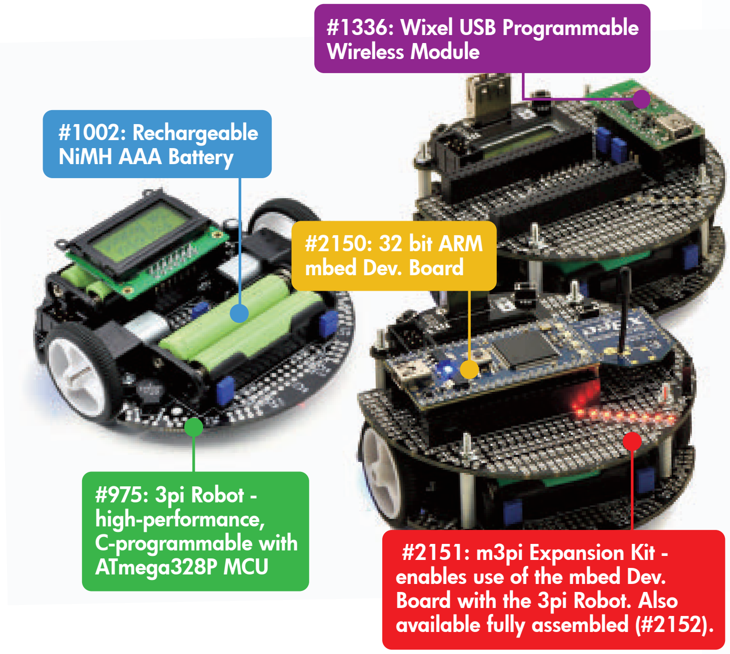
#1093: 30:1 Micro Metal Gearmotor HP

#1086: Pololu Micro Metal Gearmotor Bracket Pair

#749: Custom Laser Cutting Service - great for making custom parts quickly and economically

Robots and Robot Kits:

Pololu 3pi and m3pi



#1336: Wixel USB Programmable Wireless Module

#1002: Rechargeable NiMH AAA Battery

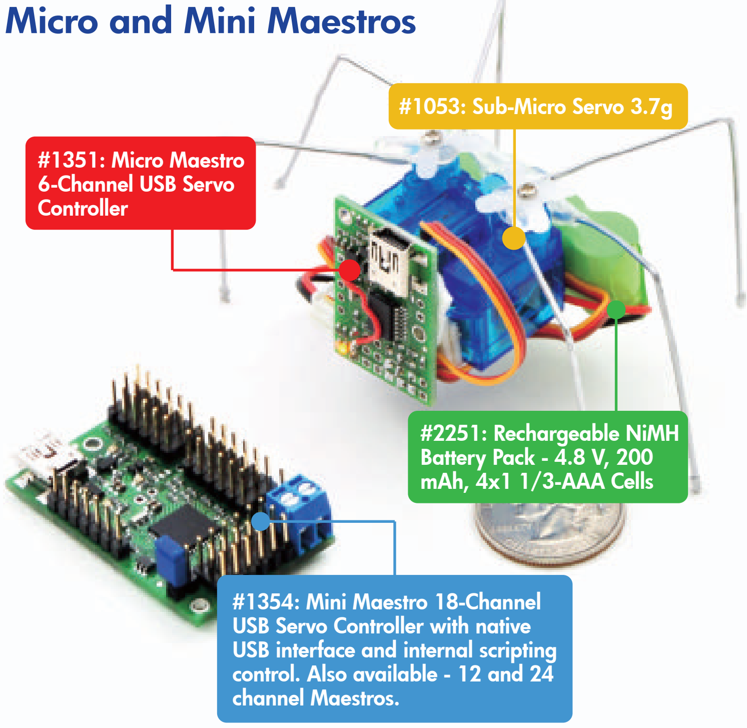
#2150: 32 bit ARM mbed Dev. Board

#975: 3pi Robot - high-performance, C-programmable with ATmega328P MCU

#2151: m3pi Expansion Kit - enables use of the mbed Dev. Board with the 3pi Robot. Also available fully assembled (#2152).

Hobby/RC Servo Controllers:

Micro and Mini Maestros



#1053: Sub-Micro Servo 3.7g

#1351: Micro Maestro 6-Channel USB Servo Controller

#2251: Rechargeable NiMH Battery Pack - 4.8 V, 200 mAh, 4x1 1/3-AAA Cells

#1354: Mini Maestro 18-Channel USB Servo Controller with native USB interface and internal scripting control. Also available - 12 and 24 channel Maestros.

Finding the right parts for your robot can be difficult, but you also don't want to spend all your time reinventing the wheel (or motor controller). That's where we come in: Pololu has the unique products - from actuators to wireless modules - that can help you take your robot from idea to reality.

Pololu

Engage Your Brain

Find these products and more at **www.pololu.com**

June 2012
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Projects & Features

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Instead of installing third-party software to crack passwords of encrypted files, try this inexpensive off-the-shelf embedded system that you don't have to connect to your computer.

■ By Nuno Alves

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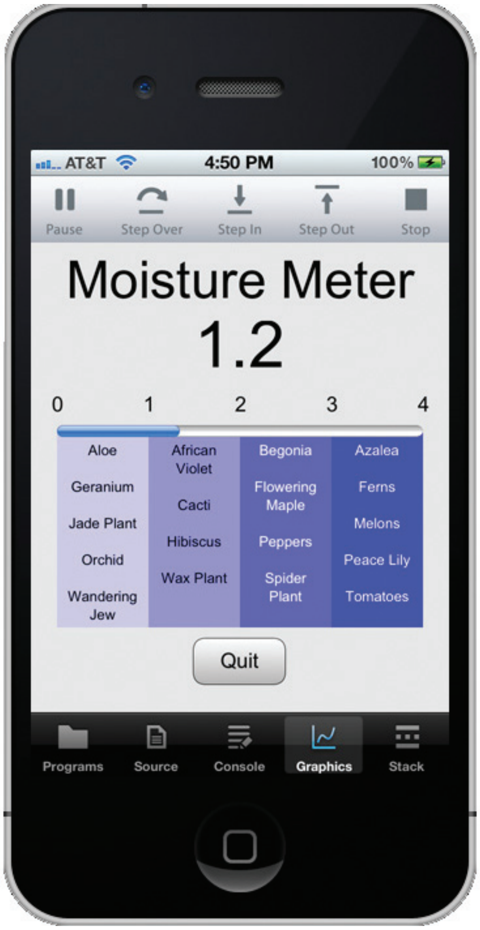
Convert an iPhone or iPad into a quadcorder and use it to "scan" for intel, like how wet or dry your plant soil is.

■ By Mike Westerfield



Moisture Meter

1.2

Aloe Geranium Jade Plant Orchid Wandering Jew	African Violet Cacti Hibiscus Wax Plant	Begonia Flowering Maple Peppers Spider Plant	Azalea Ferns Melons Peace Lily Tomatoes

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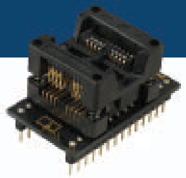
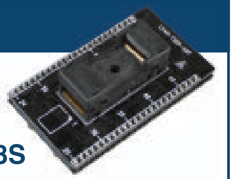
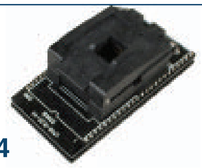


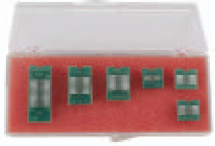
GSPA SOP-8B
8-Pin SOP to Through - Hole Prototyping Adapter



GSPA TSOP-48S
48-Pin TSOP to Through - Hole Prototyping Adapter



GSPA PLCC-44
44-Pin PLCC to Through - Hole Prototyping Adapter



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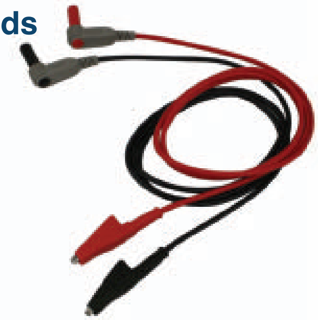
Surface Mount Device Soldering & Re-Work Tool Kit

The set includes 11 tools commonly used for working with surface mount components

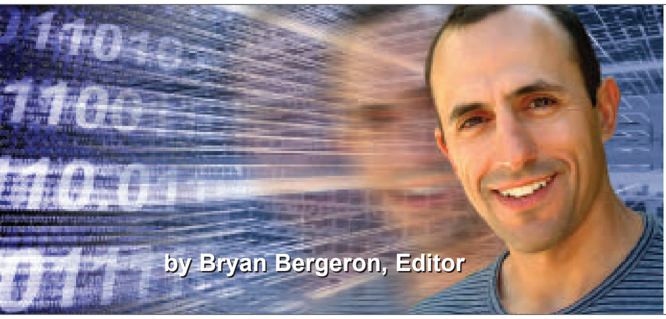
Basic Fixed Test Leads
model# CT3737

Provides users with the basic connection leads to begin using one's digital multimeter (DMM)



RDB-10 Resistance Decade Box
A compact, convenient tool for aiding in engineering design and testing as well as calibration of test equipment.

PRO-S Lab
Breadboard with External Power & Jumper Wires



by Bryan Bergeron, Editor

DEVELOPING PERSPECTIVES

Nuts & Bolts

In most of the descriptions of DIY electronics projects that I come across, the fasteners used in construction are merely mentioned in passing, if at all. However, the size, composition, and configuration of the nuts, bolts, and other fasteners can be just as important as the electronic components. Skimping on fastener hardware isn't limited to enthusiasts on a shoestring budget. The practice extends to companies that assemble thousands of devices a day.

In my work with teardowns, I often have a good idea of the quality of components and wiring in a device by the time I remove the first screw from the case. Companies that cut corners on nuts, screws, and other fasteners cut corners on components as well, which typically results in a product that fails prematurely because it can't stand up to normal use.

Similarly, your choice of fastener hardware can significantly affect the performance and longevity of your next electronic project. Let me give a few examples. Let's say you need to fasten a sheet of 1/4" thick plastic — an acrylic faceplate with countersunk holes — to a metal enclosure. Let's assume you want a nice flat finish, with no protruding hardware. The best fastener for the job is probably a flat-head machine screw — either Philips or slotted — and a matching hex nut. There are still several variables to define including size, composition, and length of the screw and the type of nut. There is also the issue of English vs. Metric measurements. For simplicity, let's stay with the more common English standard.

Given an acrylic faceplate isn't going to put a great stress on the screw, a 1" stainless steel screw with #4-40 threads should do, paired with a hex lock nut with nylon inserts. The 1" refers to the total length of the machine screw, from the surface of the flat head to the tip of the threaded end. Note that the measurement of screw length is determined by the head configuration. A non-countersunk screw would be measured along the length of the thread, and not include the height of the head.

The #4 refers to the diameter of the screw, including the threads; #4 screws are approximately 1/10th of an inch in diameter. Larger diameter screws have correspondingly larger size designations. I use #8 screws when I need something a little more secure than #4 screws. In addition, I like to use lock nuts in my projects instead of fumbling with lock washers and standard hex nuts.

Now, let's say we need to fasten a 1/8" thick metal arm to a piece of hardwood, with the proviso that the arm should be easily removed and replaced as needed. Let's say it's a metal support attached to the hardwood body of a guitar. Assuming the metal bar has countersunk holes, you might be tempted to use a common flat-head wood screw with a 1/2" clean shank. In fact, I've seen this combination.

The idea of using a wood or other screw with a clean shank is that it presents a clean, friction-free passage for the first material, but that it's in full contact with the underlying wood when the screw is fully engaged. Unfortunately, manufacturers often cut corners by stocking only one size machine screw, and use excessively long clean shanks resulting in defective joints.

In our example, the clean shank extends into the wood by over a 1/4". The clear shank is too long and extends into the wood, providing a

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less secure hold than would be possible with a screw with threads that engage along the entire depth of the wood. This not only puts excess stress on the wood, but ruins the threads in the wood for repeated assembly and disassembly.

If you're working on a project in which metal or plastic is repeatedly attached and detached from a hardwood surface, consider using E- LOK threaded inserts. Simply drill a hole in the wood, screw in the insert, and then use a standard machine screw to fasten another surface to the wood. I keep a supply of 6-32 brass inserts on hand for working with my electric guitar projects. The inserts take #6 machine screws which are thicker in diameter than #4 screws, with 32 threads per inch. Amazon sells the inserts, as well as the optional insertion tool.

As with electronic devices in general, you can develop an intuitive feel for fasteners by tearing down commercial equipment. Note the depth and angles of the countersunk holes in different materials, the thread count, and composition of fasteners. In addition, take a look at online catalogs and sources of information on fastener selection and use.

My favorite source for supplies and information on common nuts and bolts is Bolt Depot (**www.boltdepot.com**). The prices are reasonable and selection is good, but they don't carry what I consider miniature hardware — something with a smaller diameter than a #4 screw. For specialized, miniature, and exotic hardware — from brass to titanium and ceramic — I usually turn to McMaster-Carr (**www.mcmastercarr.com**). If you can't find it there, it probably doesn't exist. Even if you don't order anything from the company, the site is worth visiting for the hundreds of nicely laid out images of the various types of fasteners, including screws and head styles.

The most economical approach to acquiring a library of fasteners is to tear down every discarded electronic device you can get your hands on. Consider investing in one of those plastic compartmentalized containers for small parts. It'll save time later when you're looking for just the right fastener for the job. **NV**

READER FEEDBACK

It's History

I liked the article "The Edison Cell" in the Feb issue. I find historical articles combined with experiments very interesting. Mr. Noon mentions that they were popular in niche markets, but not for widespread use. One of the niche markets that I find interesting is in electric lighting for railroad passenger cars, where they are widely used. A generator is coupled to one wheel which provides power for lights when the car is moving. It also charges the batteries which powers the lights when the car was stopped.

— Bill Stiles

Part Number MIA

The article in the Jan issue called "The Radio Whisperer" showed a receiver circuit and a parts list but it doesn't have any information on U1 — the programmable oscillator. I need a part number for this if I am going to build it. I have spent several hours trying to locate this part. So far, I have not been able to find a DIP8 programmable oscillator. Is there any way U1 can be identified?

— John

Most any programmable oscillator will work for U1. I used Digi-Key SGR-8002DC-SHB-ND. It should be programmed for center of the WSPB band. For example, for 30M WSPR it would be 10.138700 MHz.

Continued on page 49

TECH KNOWLEDGEY 2012

EVENTS, ADVANCES, AND NEWS

■ BY JEFF ECKERT

ADVANCED TECHNOLOGY

NO GUNPOWDER REQUIRED

■ The US Navy's new railgun, built by BAE Systems.

The concept of the railgun has been around since the early 1900s, when a French inventor patented a design for his "electric apparatus for propelling projectiles." It's basically a linear motor in which two parallel rails are connected to a power supply, upon which is placed a conductive projectile that acts as an armature. This completes the circuit, resulting in a powerful Lorentz force that propels the projectile along the rails and sends it toward a target. Railguns are promising as weapons because the projectiles travel at such high velocities that they don't need to contain explosives to do serious damage. They have a few practical problems, however, as they eat up a lot of current and generate huge amounts of heat. Plus, the rails tend to disintegrate quickly. Early models essentially self-destructed in the process of firing a single round. Nevertheless, the US Office of Naval Research (**www.onr.navy.mil**) has spent the better part of a decade working on designs that hold together long enough to be practical. They recently tested the first of two commercially-built models, and it looks like a major step forward. The system — built by BAE Systems (**www.baesystems.com**) — has been run through a series of low energy shots in preparation for upcoming full-scale testing. The amazing thing about this weapon is that we're talking about 32 megajoules of power which can expel large objects at speeds of 4,500 to 5,600 mph. By comparison, an M16 rifle generates a muzzle velocity of a little over 2,000 mph.) One megajoule is enough energy to toss out a one ton object at 100 mph. The Navy's short-term goal is to demonstrate a weapon that shoots a distance of 50 to 100 nautical miles. The next goal is "to develop thermal management systems for both the launcher and pulsed power to facilitate increased firing rates of up to 10 rounds per minute." To see it in action, just search for "BAE electromagnetic railgun" on YouTube. ▲

SPOTLIGHT ON BACTERIA

It almost sounds like one of those junk-science gadgets like laser hairbrushes and magnetic water conditioners, but some Chinese and Australian scientists working at the Commonwealth Scientific and Industrial Research Organisation (CSIRO, **www.csiro.au**) have come up with a handheld, battery-powered plasma flashlight that instantly kills bacteria. In experiments detailed in a recent issue of the *Journal of Physics D: Applied Physics*, the device inactivated a slew of a highly antibiotic- and heat-resistant bacteria — Enterococcus faecalis — which often infects the root canals during dental treatments. As explained by Prof. Ken Ostrikov, "The bacteria form thick biofilms which makes them enormously resistant against inactivation. High temperatures are commonly used, but they would obviously burn our skin. In this study, we chose an extreme example to demonstrate that the plasma flashlight can be very effective even at room temperature. For individual bacteria, the inactivation time could be just tens of seconds."

The biofilm specimen treated consisted of 17 different layers of bacteria, 25 m in thickness. After a five minute treatment, it was observed that the flashlight not only killed off the top layer of cells, it penetrated deep enough to kill the bottom of the layers of bacteria, as well. The device emits a plume of plasma at between 68°F and 74°F (20°C and 23°C), so it cannot harm the skin. The exact antibacterial mechanism is not known, and one might surmise that UV radiation present in the plume could account for it, but the UV content is actually very low. It is therefore believed that the reaction between the plasma and surrounding air creates "a cocktail of reactive species that are similar to the ones found in our own immune system." According to its developers, the device should prove useful in such applications as ambulance emergency calls, natural disaster sites, combat operations, and pretty much wherever treatment is required in remote locations. Best of all, a commercial version should cost less than $100. ▲

Portable Plasma Flashlight ® by HUST

■ CSIRO's plasma flashlight is deadly, but only to bacteria.

Discuss this article in the *Nuts & Volts* forums at http://forum.nutsvolts.com.

COMPUTERS AND NETWORKING

NEW ENTRY TO SMARTPHONE MARKET

■ Nokia and Microsoft team up to give the iPhone another competitor.

It seems like a risky concept, given that neither Nokia (**www.nokia.com**) nor Microsoft (oh, you know the URL) has had any real success in the US smartphone market, but the two have teamed up to generate the Lumia 900: a competitively priced unit that runs on AT&T's 4G LTE network using Windows Phone software. With a two year contract, it comes in at $100 which beats most other LTE smartphones. It features a 4.3 inch AMOLED ClearBlack display and a 16 Mpixel camera with large aperture (f/2.2), wide-angle (28 mm) Carl Zeiss optics. You get up to seven hours of use from the 1,830 mAh battery. As of this writing, your color choice is between black and a somewhat questionable shade of cyan, but white ones should be available by the time you read this. Reviews of the Lumia have been largely positive, although some observers have complained about a relatively small collection of available apps. Will the low price and larger screen lure the masses away from the iPhone? Time will tell. ▲

SCANNER FEATURES WI-FI MEMORY

■ The Xerox mobile scanner lets you scan documents wherever you go.

It's hard to imagine wanting to scan a stack of documents while riding around in a taxi or catching some sun at the beach, but apparently there is a market for portable color scanners. One of the latest entries is the Xerox Mobile Scanner (**www.xerox.com**). Perhaps the most interesting thing about it is that it features a 4 GB Eye-Fi SD memory card — billed as the world's first wireless memory device. It works with Wi-Fi networks so you can transmit JPG and PDF files directly from the scanner to a computer, mobile phone, pad, or whatever. A free mobile app lets it communicate via a PC, Android, Mac, iPhone, iPad, iPod Touch, or the Cloud. Note that its maximum optical resolution is 300 dpi which may be an issue for a few people. The device measures only 2 x 2.75 x 11.5 in (5 x 7 x 29 cm) and comes with a carrying case, rechargeable battery, and charger. The retail price is $249.99, but the street price is a little lower. Before you place your order, though, think about how much having the Xerox name on it means to you. The device sure looks like a clone of the Mobility Mobile scanner from licensing partner Visioneer. You can pick one of those up for about $100 less. ▲

CIRCUITS AND DEVICES

3D TV MINUS THE SCREEN

■ Epson's Moverio BT-100, billed as the world's first Android-based, see-through wearable display.

The parade of 3D video products continues unabated, but Epson's Moverio™ BT-100 is a major variation on the theme. The Android-based device eliminates the screen completely since it's a wearable display that lets you view streaming video via microprojectors and a track pad controller, providing a virtual 80 inch perceived "floating" screen. Users can also view downloaded content from the microSDHC card slot (4 GB card included) and 1 GB internal storage, so you can still use it where wireless network access is unavailable. Because you can simultaneously see what's going on in the world around you, the Moverio is also useful for existing and future "augmented reality" applications (i.e., enhancing or possibly diminishing your view on reality with computer-generated input). However, wearing them while driving or performing brain surgery may not be advisable. Other features cited by Epson include nearly six hours of battery life, up to 32 GB of program storage, Adobe Flash 11 support, and Dolby Mobile surround sound. Even though the BT-100 eliminates the big screen it still comes at a big price, listing for $699. Details are available at **www.epson.com/moverio**. ▲

CIRCUITS AND DEVICES CONTINUED

FLEX DISPLAYS IN PRODUCTION

■ LG's electronic paper display is only 0.7 mm thick and bends up to 40°.

After years of hearing about future flexible displays — known as e-paper — it appears that the future is finally here. In late March, LG Display (**www.lgdisplay.com**) announced that it was starting mass production of "the world's first plastic electronic paper display (EPD) for use in e-books." The device is a six inch extended graphics array (XGA) screen (1024 x 768 resolution) that has a flexible design that allows it to bend as much as 40° from the center of the screen, is only 0.027 in (0.7 mm) thick, and weighs just 0.49 oz (14 g). In addition to the flexibility and weight reduction, the display will be more durable than current rigid ones which often are damaged by accidentally dropping or hitting them with an object. LG's tests showed that with repeated drop tests from five feet (1.5 m) above the ground, no damage occurred. Furthermore, whacking it with a "small urethane" hammer created no scratching or breakage. LG wasn't very specific about how it has accomplished this feat, but it was revealed that the company "developed a unique technique to utilize the high TFT process, typically employed in general LCD manufacturing and with temperatures exceeding 350°, in the production of its plastic EPD ... overcoming the obstacles associated with applying the existing production process to heat-susceptible plastic." The displays will be made available to original design manufacturers (ODMs) in China immediately, with completed products to be available in Europe first. Presumably, we will begin to see them here shortly thereafter. ▲

INDUSTRY AND THE PROFESSION

BIG TELESCOPE FOR THE BIG BANG

■ A few of the millions of antennas required for the SKA.

In case you haven't heard about it, the folks at the Square Kilometre Array (SKA) Organisation (**www.skatelescope.org**) are working on the world's largest and most sensitive radio telescope, to be completed in 2024. Upon completion, the telescope will be used to explore evolving galaxies, dark matter, and even the very origins of the universe, dating back more than 13 billion years. The scope will actually be made up of millions of antennas, forming a collection area equivalent to a square kilometer but actually spread out over an area more than 3,000 km wide. This will give the world a device that's 50 times more sensitive and 10,000 times faster than any previous one. The catch, however, is that it will generate a few exabytes (i.e., 1,000,000,000,000,000,000 bytes) of data every day — equivalent to double what presently goes over the Internet. This will take some pretty gritty processing power, plus enough storage for between 300 and 1,500 petabytes of processed data per year. Never fear, though, since the Netherlands Institute for Radio Astronomy (ASTRON) and IBM (**www.ibm.com**) have teamed up in the "design, engineering, and manufacturing of customized, high performance, low power analog and mixed signal processing chips for an SKA prototype system." With an initial grant of 32.9 million Euros, the five year collaboration will end up with a new supercomputer based in Drenthe, Netherlands at a newly established ASTRON and IBM Center for Exascale Technology. To keep up to date on the project, visit **www.astron.nl**. **NV**

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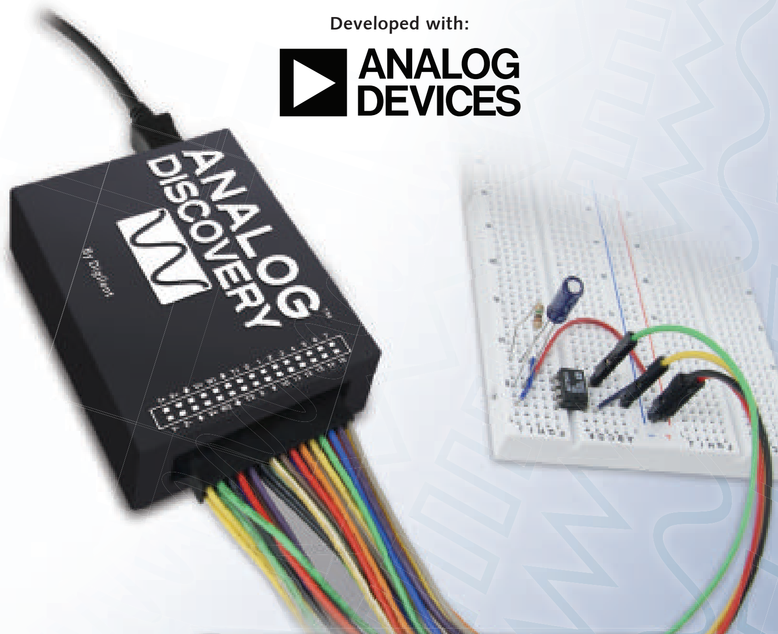

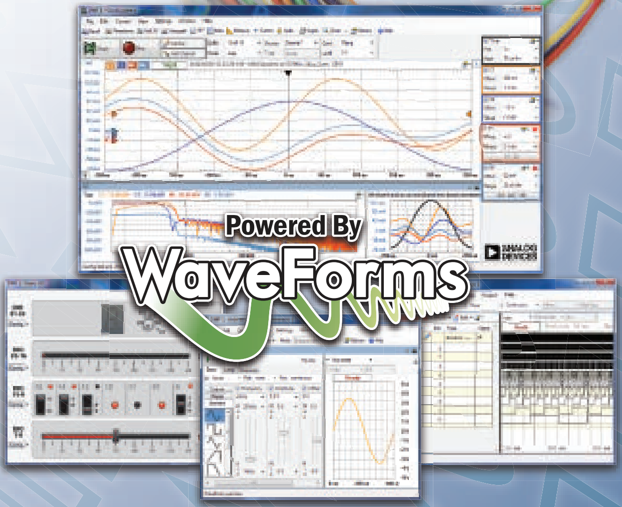

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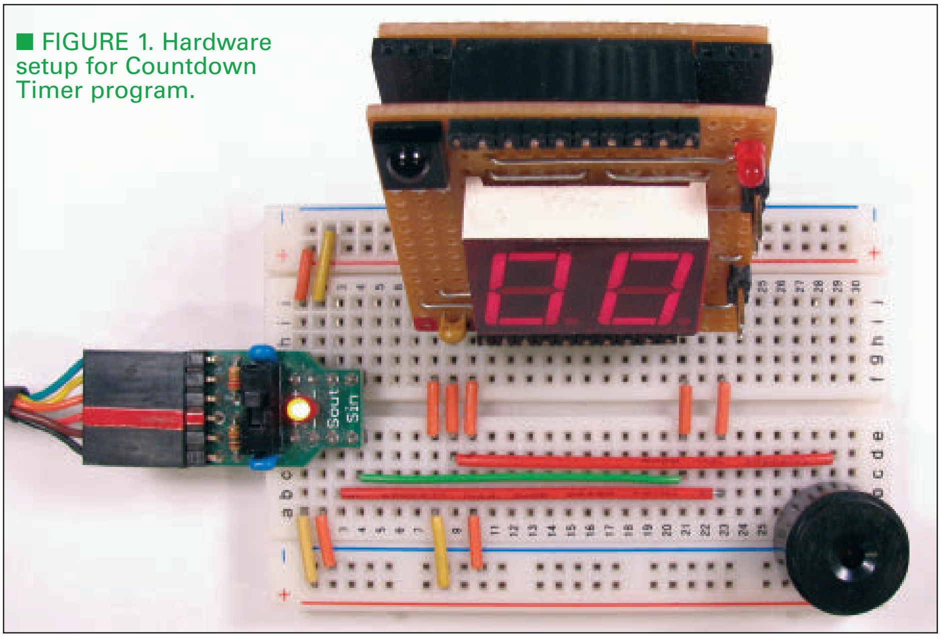
■ BY RON HACKETT

INTERFACING THE DS18B20 DIGITAL THERMOMETER

As I mentioned last time, we still have more features of the LED-2x7 board to explore. This month, we're going to use a TV remote control to add the capability of user input to our LED-2x7 project, and then move on to exploring some of the details of implementing the temperature measurement features of the PICAXE-20M2 processor. Everything we'll be discussing this month is applicable to any M2-class processor; so you don't really need an LED-2x7 for our experiments. A simple 20M2 breadboard circuit will suffice for all our experiments this month. I'll include two versions of each program we use: one for the LED-2x7, and one for a breadboard circuit without an LED display.

Before we get started, there's an issue that we need to discuss. As you know, Panasonic has discontinued production of the PNA4602 IR receiver that we have used in all our earlier IR projects. Therefore, if you don't already have access to a PNA4602, you will need a suitable replacement. Essentially, what's required is an IR receiver that operates at 38 kHz, is pin-compatible with the PNA4602, and doesn't require any additional parts for its operation. (Pin compatibility is only necessary if you want to use the device in any of the IR boards on my site.)

I have been testing Vishay's TSOP34338 device which meets all three of my requirements, and I've been able to consistently use it with reliable results at distances up to 30 feet indoors. So, I plan to add the TSOP34338 to the parts on my site. Of course, you can also use any other IR receiver that works reliably with the PICAXE *irin* command.



■ FIGURE 1. Hardware setup for Countdown Timer program.

IMPLEMENTING USER INPUT ON THE LED-2X7 BOARD

As I also mentioned last time, we've already discussed IR input in previous installments of the Primer (Oct and Dec '08, Feb '09, and Aug '10), so we won't rehash all the details again. If there's anything that's not clear this month, you may want to review the relevant *N&V* articles. Also, if you have a copy of *PICAXE Projects for the Evil Genius*, Chapter 8 focuses on the use of a TV remote with M2-class processors.

The first task we need to accomplish is to make sure the LED-2x7 board is correctly receiving our IR input. We're going to use two different programs for this purpose (*IRtest.bas* and *LED2x7-IRtest.bas*) because I also want to demonstrate how to use the *sertxd* command if you are using a breadboard circuit rather than the LED-2x7 board. These two programs — along with the other programs we will be using this month — are available for downloading from the article link.

So, let's begin with the simpler program, *IRtest.bas*. Download it to your LED-2x7 board or your breadboard circuit. If you are using a breadboard circuit with an M2 processor other than the 20M2, you will first need to modify the *#picaxe* directive (and possibly the *symbol IRpin* = *C.6* instruction, as well). Whenever you press a key on your SIRC-compatible TV remote, you should see a number displayed in the terminal window. You can refer to the documentation for the *irin* command in Section 2 of the PICAXE manual to check that the correct value is being received for each key press.

If the program doesn't work for you, try pressing the "TV" button on the remote to configure it for the SIRC TV codes. If that doesn't improve the situation, you will need to debug your circuit. If you are using an LED-2x7 board, you can also download and run the *LED2x7-IRtest.bas* program. In this case, the *irin* values will be shown on the board's display.

When your setup (breadboard or LED-2x7) is functioning correctly, we're ready to move on to our next program (*CountdownTimer.bas* or *LED2x7-CountdownTimer.bas*) which is where the fun really begins! We're going to implement a simple countdown timer that's settable via the TV remote. Of course, any self-respecting countdown timer needs an annoying beeper to tell the user when the selected time period has expired, so we're going to add a piezo beeper to our hardware setup.

Any piezo you have on hand should work; there's also one available on my website. Since we aren't using the DS18B20 yet, the 20M2's C.7 pin is available, so that's where I have connected the positive terminal of the piezo, with its negative terminal connected to ground.

Figure 1 is a photo of my hardware setup for the timer. I used a few more jumpers than necessary in order to make all the connections clearly visible. As you can see, I have connected my AxMate-FT programming adapter to the appropriate pins on the right-side breadboard connector of the LED-2x7. (I didn't connect ground at that point because it's already connected to the left-side breadboard connector.) Of course, you can also use the programming adapter connector at the upper-right corner of the LED-2x7 if you prefer.

In the Countdown Timer program, I have assigned five of the remote's keys to implement the following functions:

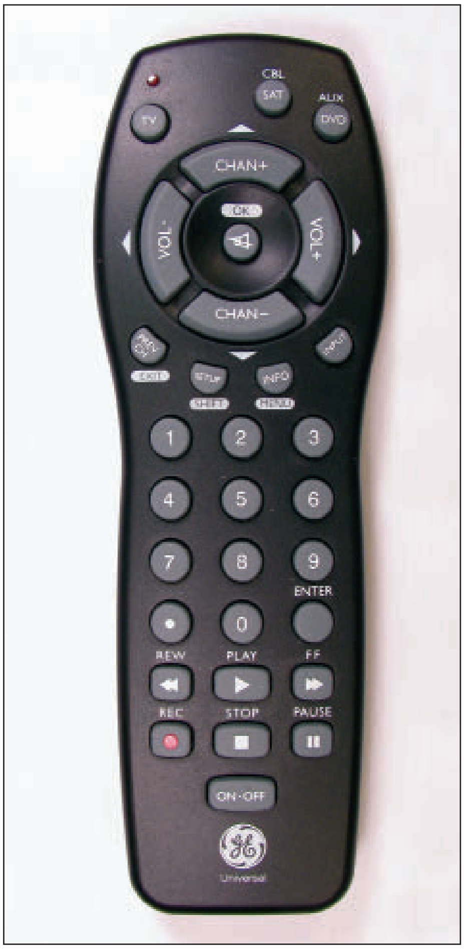
- **CHAN+:** Add 10 to the second counter
- **CHAN-:** Subtract 10 from the second counter
- **VOL+:** Add 1 to the second counter
- **VOL+:** Subtract 1 from the second counter
- **MUTE:** Start the timer/Stop the alarm

If you look at **Figure 2** (which is a photo of the TV remote that I'm using — available at the Home Depot), you can see why I chose the keys and functions that way. On my remote, the CHAN and VOL keys are arranged in a diamond-shaped pattern that's fairly common on remote controls. In addition, the MUTE key is in the center of the diamond. As a result, I can easily program my countdown timer without looking at the remote at all.

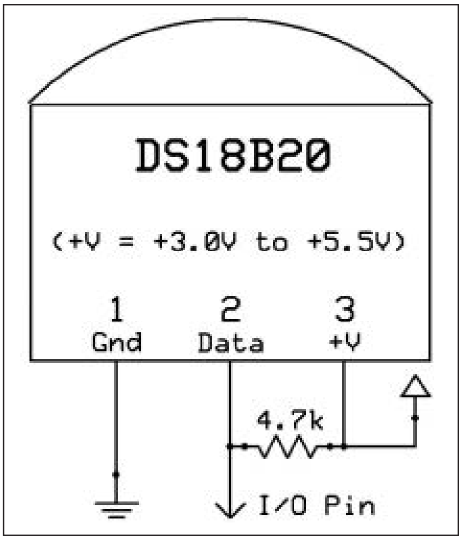
If your TV remote has a different layout, you may want to reassign some of the keys. Before you do that, it would be a good idea to make sure that the program functions correctly with your setup.

The countdown program is thoroughly commented, so it doesn't require much clarification. However, I think this is the first time we have used the PICAXE *exit* command (even though it's been around for a while), so that may require a bit of an explanation. The *exit* command only functions inside two specific structures: a *do/loop* and a *for/next* loop. Its purpose is to immediately terminate the execution of either of these structures, and to continue program execution at the next instruction. Sometimes this can be a little confusing. For example, in the countdown program, the *exit* command is inside the *select case* statement, so it would be reasonable to think that it's the *select case* statement that's being terminated. If so, the *gosub displayValue* statement would be executed next. However, it's the *do/loop* that contains the *exit* command that is actually being terminated, so the program moves on to the *time* = *0* statement, and begins the countdown.

The second *do/loop* in the

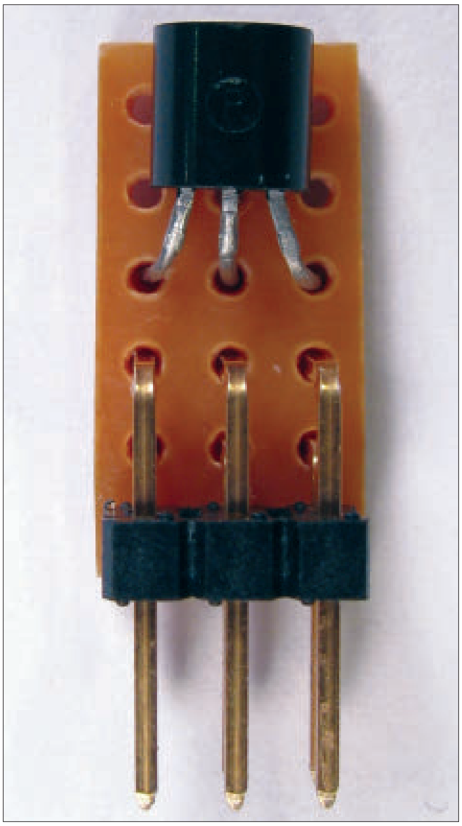


■ FIGURE 2. Typical universal TV remote control.



■ FIGURE 3. DS18B20 pinout and I/O circuit.

program implements the countdown, and the third *do/loop* is responsible for the annoying alarm that persists until the user presses the MUTE key on the remote. When you're ready, download the program to your setup and run it. You should be able to set the countdown timer with the VOL and CHAN keys, start it running with the MUTE key, and silence the alarm when it occurs by pressing the MUTE key.



■ FIGURE 4. DS18B20 mounted on a small stripboard.

MEASURING TEMPERATURE WITH A PICAXE M2 PROCESSOR

PICAXE BASIC includes the following three built-in temperature measurement commands that greatly simplify the tasks of temperature monitoring and data collection:

- **Readtemp** - Read eight-bit temperature from a DS18B20 digital temperature sensor
- **Readtemp12** - Read full 12-bit temperature from a DS18B20
- **Readinternaltemp** - Read internal temperature of an M2-class processor

The first two commands are available on all PICAXE processors, including the older M-class chips; the *readinternaltemp* command is only available on M2-class processors.

Readtemp is the simplest of the three commands, so let's begin there. It requires the Dallas Semiconductor DS18B20 digital temperature sensor. As indicated above, *readtemp* obtains the eight-bit digital temperature from –55ºC (-67ºF) to +125ºC (257ºF), and is accurate within ±0.5ºC, from –10ºC (+14ºF) to +85ºC (+185ºF). (Celsius is fine for most of the western world, but we're still dragging our feet in the US, so we will soon be punished by having to convert the result to Fahrenheit!)

There are three details of the *readtemp* command that are important to keep in mind. First, *readtemp* requires up to 750 mS to obtain the temperature which is much longer than most other PICAXE BASIC commands. Second, during the measurement cycle, the communication between the PICAXE processor and the DS18B20 is bi-directional which means that the sensor must be connected to a bi-directional I/O pin. On the 20M2, for example, pin C.6 cannot be used because it's fixed as an input.

Finally, *readtemp* only works at a processor speed of 4 MHz. Fortunately, all X1, X2, and M2 processors automatically switch to 4 MHz when a *readtemp* command is executed, and then switch back to whatever speed had been in effect before the command was executed. If you use an older M-class processor, however, your program will need to adjust the speed up or down as needed.

If you're interested in more of the details of the *readtemp* command, you can refer to Section 2 of the PICAXE manual, but we're ready to try out our first temperature program. For this one, we'll keep it simple by using the default Celsius reading, and just displaying it in the terminal window. Before we get to our program, however, let's take a look at how to connect an 18B20 to a PICAXE processor.

The hardware requirements are minimal; the only requirement is that the 18B20's data pin must be pulled high by a 4.7K resistor. (**Figure 3** presents the DS18B20 pin-out, as well as the complete I/O circuit.) We have already included the necessary resistor on the LED-2x7 board, but if you're using a breadboard circuit just connect it as shown in **Figure 3**.

Before we get to the software for our first temperature experiment, I want to mention a little problem I had along the way. I was using the LED-2x7 board, so I just plugged the 18B20 into the three-pin I/O connector at the top-left corner of the board. I was careful to insert the 18B20 with its flat side to the back, because the three-pin connector has its +V pin on the left and its ground pin on the right, so the 18B20 has to be inserted with its rounded surface facing front. (**Warning:** Accidentally reversing the +V and ground connections on the 18B20 can damage or destroy the sensor, and possibly the PICAXE processor, as well!)

When I ran my first program, the results were a bit odd. Usually, I got the temperature reading I expected (around 22ºC, which is about room temperature), but occasionally a result of 0ºC would show up in the data as the program looped. It turned out that the problem was caused by the fact that the pins of the 18B20 are too thin to make a reliable contact with the pins of the female header on the LED-2x7 board.

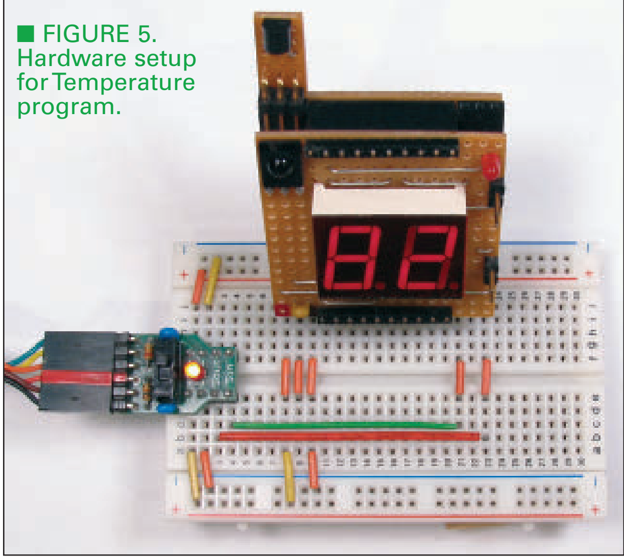
The solution was simple. I made a very small stripboard circuit (three rows of six holes each) and soldered the 18B20 (again, rounded side to the front) and a three-pin by two-row male header to the stripboard (see **Figure 4**). I had planned to use a stripboard anyway, because I want to be able to locate the 18B20 some distance from the board. (We'll see why shortly.) The reason I used a 3x2 male header is that I want to be able to use a piece of ribbon cable with 3x2 IDC connectors on each end to connect the 18B20 to the LED-2x7 board.

If you're using a breadboard circuit, none of this is necessary; the 18B20 can be plugged directly into the breadboard. On the other hand, if you're using the LED-2x7 board, you may want to construct the stripboard circuit before going further.

My hardware setup for our first temperature program is shown in **Figure 5**. The back row of three pins on the18B20 stripboard is inserted into the three-pin connector on the LED-2x7. (There's ample room for the front row of pins to fit between the LED-2x7's two stripboards without coming into contact with anything.) The program we'll be using is simple enough that you can just type it into the Programming Editor or AXEpad:

```
symbol temp = w0
#terminal 4800
do
  readtemp C.7, temp
  sertxd (#temp, CR, LF)
  wait 1
  sertxd (CR, LF)
  wait 1
loop
```

In the first instruction in the loop, we get the temperature (in Celsius) from the 18B20 that's connected to pin C.7 and store the obtained value in the *temp* variable. Next, we send the value (digit by digit), followed by a carriage return, and a line feed to the terminal window that we opened with the initial directive. The second *sertxd* instruction may seem odd, but when you run the program you will see how it scrolls the data in the terminal window so that it's clear when a new line is being printed. (Try the program with and without the second *sertxd* instruction and you will see the difference it makes.) Finally, the two *wait* instructions simply slow things down a bit.


■ FIGURE 5. Hardware setup for Temperature program.

When you run the program, you should get a reading somewhere near 22ºC, assuming you're in a typical indoor environment. If you hold the 18B20 an inch or so from your mouth and exhale directly on it, you should see the temperature rise by a couple of degrees or more.

When everything is working correctly, we're ready to take the next step: converting Celsius to Fahrenheit. For our first attempt, we're going to simplify things and ignore temperatures below freezing. (We'll correct for that later.) If we do that, it's really a simple exercise. In case you don't remember the formula for this purpose, it's F = 9/5 * C + 32. All we need to do is program the three operations in the same order that we would do the calculations. The only caveat is that we need to use a word variable for this purpose, because we're going to be multiplying by 9. So, if the starting point is 29ºC or greater, multiplying by 9 would overflow a byte variable and produce incorrect results. Here's a little code snippet that accomplishes the task:

```
symbol temp = w0
temp = temp * 9
temp = temp / 5
temp = temp + 32
```

That's all there is to it. In fact, we can make it even simpler by taking advantage of the fact that PICAXE BASIC performs calculations strictly from left to right in an instruction. Therefore, we can combine our three calculations into one program line:

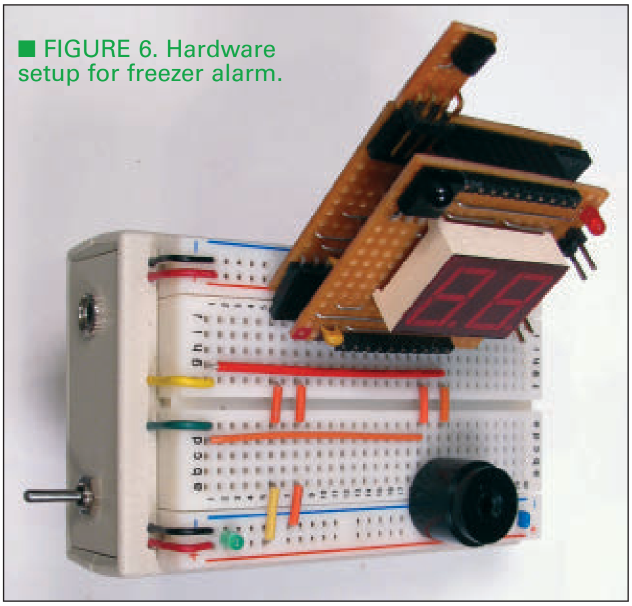
```
temp = temp * 9 / 5 + 32.
```

In the code snippet we just ran, change *temp* to a word variable, add this program line right after the *readtemp* instruction, and run the program again. This time, you should get temperature readings somewhere near 72ºF.

In the first LED-2x7 Primer column (Feb '12), I mentioned that I had been working on three different projects that ultimately led to the creation of the LED-2x7. One of the projects is a temperature alarm for the freezer in my basement. This was motivated by an accidental unplugging of the freezer that resulted in the spoilage of a large amount of frozen food, and a considerable mess.

Determined to avoid any similar problems in the future, I decided to dedicate a PICAXE circuit to monitoring the temperature of the freezer, and warning me if it ever becomes greater than 20ºF. Of course, in order to accomplish this goal, the circuit had to function correctly when the measured temperature was below freezing. So, I could no longer use the simple one-line conversion that we just discussed.

Naturally, the final conversion routine to handle temperatures below freezing functions analogously to the way we humans would do it. For



■ FIGURE 6. Hardware setup for freezer alarm.

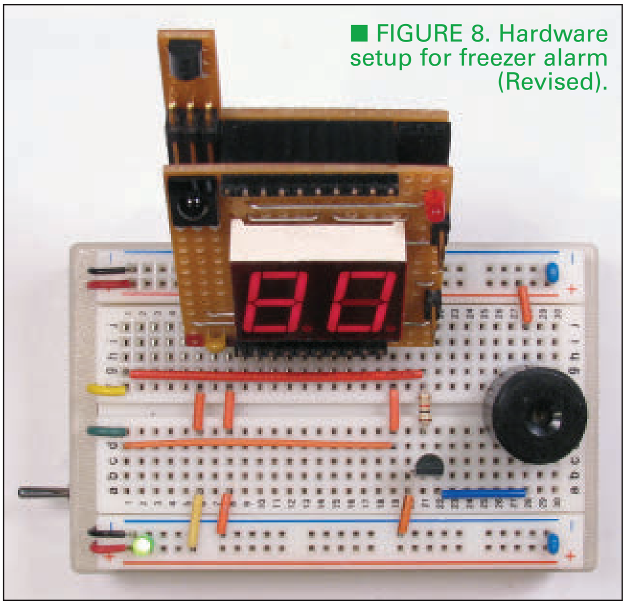
example, if the measured temperature were –5ºC, we would take the following three steps:

```
-5 * 9 = -45
-45 / 5 = -9
-9 + 32 = 23
```

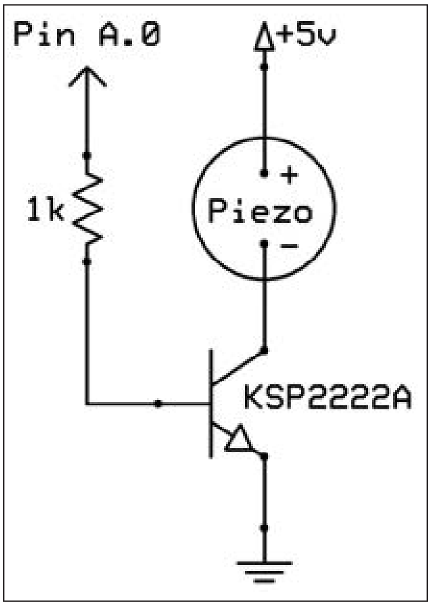
These are the same three steps we just discussed with positive temperatures, except that when we add –9 and 32, we actually subtract their magnitudes. Therefore, our conversion routine needs to have three distinct steps:

1. Determine (and remember) whether the measured value (in Celsius) is below 0.
2. Multiply the measured value by 9 and then divide the result by 5.
3. If the original value was above 0, then add the converted value to 32; if not, subtract the original value from 32.

Fortunately, PICAXE BASIC provides a simple way to accomplish Step 1: If the measured temperature is below 0, bit 7 is set to 1. In other words, the compiler adds 128 to the magnitude of negative temperatures. For example, if the measured temperature is –5ºC, *readtemp* will obtain a value of 133 (i.e., 5 + 128), so we can use an *if/then/else* statement to determine whether a value is negative or positive, and set a *negFlag* variable for negative temperatures or clear *negFlag* for positive temperatures. We already know how to accomplish Step 2 (temp = temp * 9 / 5), and Step 3 just requires another *if/then/else* statement – if *negFlag* is clear, then add the temperature to 32; if not (below freezing), subtract the temperature from 32.



■ FIGURE 8. Hardware setup for freezer alarm (Revised).



■ FIGURE 7. Improved piezo circuit for freezer alarm.

Our next program (*Temp.bas* or *LED2x7-Temp.bas*) implements the above approach to handling negative temperatures. Examine the *C2F* subroutine in the program to see one way that the above steps can be implemented in software. Of course, you won't be able to test how the program handles temperatures below freezing until you construct a cable for the 18B20 so that you can actually place it in a freezer.

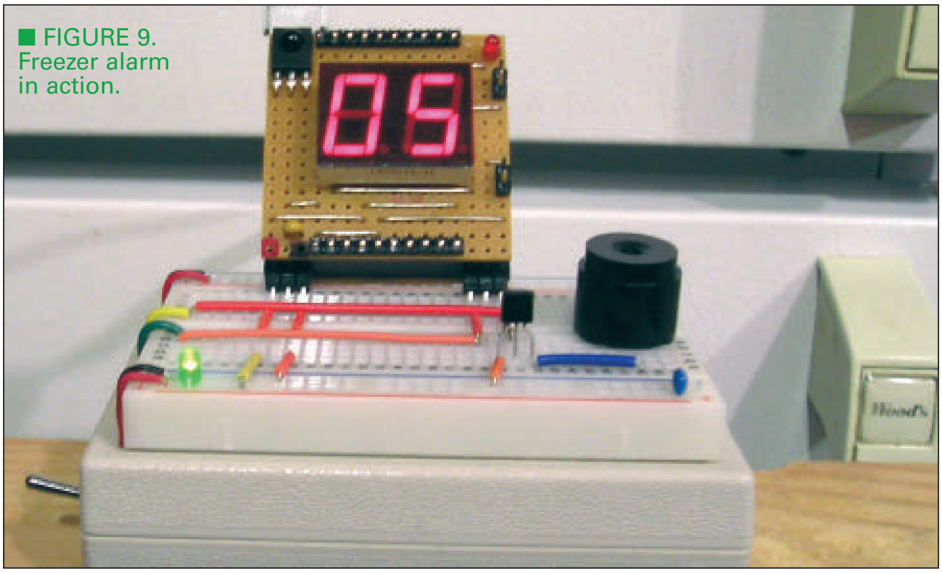
You can use the same ribbon cable setup that I mentioned earlier, or any other three-wire cable you may have handy. (The advantage of the ribbon cable is that it's thinner than most other cables, so the rubber insulation on the freezer door can still seal effectively with the cable in place.) Now would be a good time to construct a cable, because you will need one to test our final program this month, which implements the freezer alarm I mentioned earlier.

AN LED-2X7 FREEZER ALARM

At this point, we have already discussed most of the features needed for an effective freezer alarm; all that remains to be accomplished is to configure the "danger" temperature that we want to use, and to implement the alarm itself. Configuring the danger temperature is easy, but implementing the alarm is a bit more of a challenge. A blinking LED simply won't do; we need a more attention-getting output – like the annoying sound of a piezo beeper. The problem is that we seem to have already used all of the 20M2's remaining I/O resources. Pin C.6 is dedicated to the IR receiver, and pin C.7 is used for our 18B20 temperature sensor.

Of course, we don't need the IR receiver for a freezer alarm, but pin C.6 is fixed as an input, so it wouldn't help us anyway; all that's left is pin A.0. As you may remember from the Feb '12 article, we discovered that we could use the 20M2's A.0 "pseudo" output to blink an LED by writing a sequence of appropriate instructions (e.g., *high A.0 : wait 1 : low A.0 : wait 1*). It occurred to me that we might be able to toggle the A.0 output fast enough to produce a usable sound with a piezo beeper.

To test this idea, I removed jumpers J6 and J7 from the LED-2x7 board, disconnecting the discrete LED and the decimal point from the A.0 output pin, so it can be used for another purpose. As you may also remember, the A.0 pin is available at pin 3 of the J4 breadboard connector (see the LED-2x7 schematic in the Feb '12 Primer), so I added the beeper between that pin and ground on my breadboard (see **Figure 6**).



■ FIGURE 9. Freezer alarm in action.

The breadboard in the **photo** is attached to a small project box that contains a nine volt battery, a simple +5V regulated supply, and an on-off switch that controls power to the breadboard. In addition, there's a female stereo jack mounted on the side of the box, and the PICAXE programming interface is also inside the box. The green and yellow jumpers near the middle of the left edge of the box are connections to the *serin* and *serout* lines (respectively) from the programming adapter.

I used this setup because I wanted to avoid the hassle of connecting to an external power

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supply every time I moved the setup back and forth between my computer and my freezer. If you don't have a battery-powered setup, you could easily accomplish the same thing by attaching the battery to the breadboard with a rubber band and wiring the supply components directly on the breadboard (but a battery-powered setup is a simple project that's easy to construct).

Using this setup, I experimented with several variations of an alarm routine. My goal was to mimic the alarm on my kitchen timer, and the final version comes pretty close (see *Alarm20M2.bas*).

Two points are worth mentioning. First, the program runs at 16 MHz because I couldn't produce beeps that had a sufficiently high frequency at lower speeds. As I mentioned earlier, this isn't a problem for the 18B20 because the compiler automatically slows the processor to 4 MHz for each temperature reading, and then returns it to 16 MHz after each reading.

The second point is more important. I discovered that I wasn't able to download the program to the LED-2x7 with the piezo in the circuit. For some reason, the Programming Editor thought the processor was a 20X2 when the piezo was present, and refused to download the program. (Don't forget, A.0 is also the *serout* pin which is used in the programming process.)

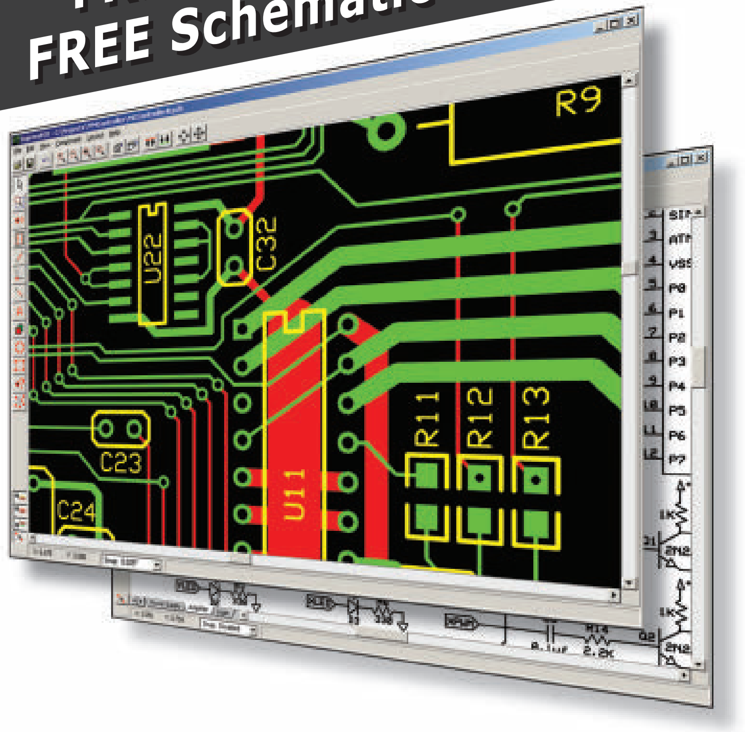
Therefore, I had to remove the piezo each time I downloaded a new version of the alarm routine. This quickly became a nuisance, so I isolated the piezo from the *serout* pin by buffering it with a KSP2222A NPN transistor. The revised I/O circuit is shown in **Figure 7**; **Figure 8** is a photo of the final breadboard setup. This arrangement made the Programming Editor happy; downloads proceeded without a problem.

In addition, there was a second major benefit. The piezo was much louder because it was being driven by the transistor, so there's no chance of my not hearing it if my freezer has another problem.

The final program (*LED2x7-FreezerAlarm.bas*) incorporates many of the features we have discussed this month, plus one that I added after testing the program a few times. My freezer usually operates somewhere between 5ºF and 10ºF, and I wanted to set the alarm temperature at 20ºF. As I was testing the program (see **Figure 9**), I discovered that, if I opened the freezer for more than a few seconds, the alarm would sound.

The only way to shut it off was to power-down the program and restart it, so I added a couple of lines of code that exits the alarm *do/loop* in a situation like that. Now when I shut the freezer door, the alarm shuts off in a few seconds.

Well, we're out of space again, so we'll continue our investigation of the DS18B20 next time. In addition, we'll experiment with the new M2-class *readinternaltemp* command. In the meantime, have fun! **NV**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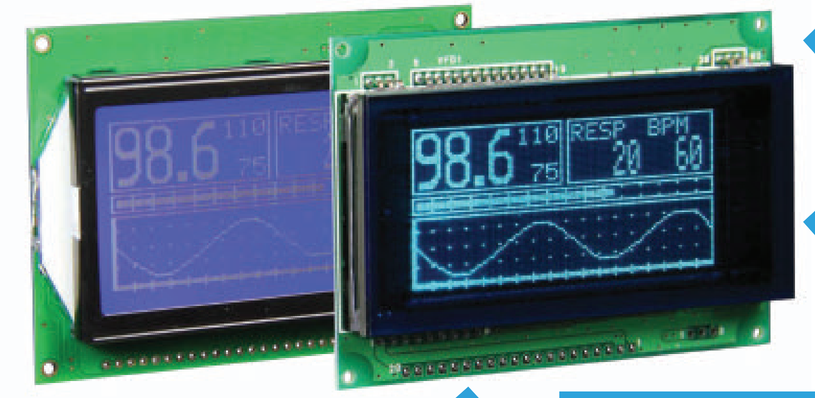

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Ahh!!... the conveniences of today's technology in our modern world! Voice recognition, LED's instead of incandescent bulbs, on-board computers, on-board hard drives, automatic parallel parking, automatic radar cruise control, and of course, wireless remote controls! They make it so simple, just have the "key" (called a key fob) somewhere in your pocket or purse, get near the vehicle, it knows that you are there! Touch the door handle and the vehicle unlocks. Get in and touch the start button and the vehicle starts. You have yet to use a key through the whole process! And don't forget all the wireless controls for your house lights, building access and entertainment systems. They're so great… until they don't work!

Just like the days of "plugs, points, and condenser" are over, so are the days of having the hardware store grind out a spare key for your car! Now when your keyless access system doesn't work, you need to accurately detect what part of the system is malfunctioning. This could be anything from a dead battery in the key fob, a "brain-dead" key fob, to malfunctioning sensors, antennas, or other system components in the vehicle. The WCT3 is designed for both the car dealer service shops as well as the consumer. Until now there was no way to determine where the system was failing. Please note that the WCT3 simply verifies the generation of the control signals. Indication of signal presence is not an indication the encoded data is valid, nor is it a reader of that code, so don't worry, this will not help anyone steal your car!

First, let's cover a few basics about vehicular keyless entry. In general, (not all systems are created equal), the vehicle itself generates a signal at 125 kHz or 20kHz. This is the signal that is used to "talk" to your individual key fob. Upon receiving the signal, your key fob "returns" a 315MHz signal uniquely encoded with an identification code and unlock command. If the embedded codes of the vehicle and your key fob match, you're in! Once you have "unlocked" the vehicle, and are inside the vehicle, the presence of your key fob is detected in the same way when the "start" button is pressed. If the codes match, the vehicle can be started. Some manufacturers also use Infrared (IR) signals in their key fobs to add additional user control functions to the vehicle. In that case, the key fob generates a modulated IR signal that is received by the vehicle's IR detectors placed throughout the perimeter of the vehicle.

Testing your system is easy. To test the complete 125 kHz/315 MHz communications path just stand close to the vehicle with the WCT3 and your key fob in hand. Press the test button and the WCT3 will detect and display the presence of the vehicle's 125kHz/20KHz signal and, if they "handshake", will also detect and display the presence of your key fob's 315MHz return signal. You can independently test key fob only signals (panic, lock, trunk, etc.) by holding the key fob near the WCT3, pressing the test button, and pushing the function button on the key fob. The same functionality testing can be done with IR key fobs. The modulated IR signal is detected and will illuminate the IR test LED on the test set. If you know a few "secrets" you can also see if the tire pressure sensors/transmitters are generating signals or the built-in garage door opener in your rear view mirror is transmitting a signal! But the WCT3's uses go beyond the automotive world. The majority of building wireless access systems also utilize 125 kHz. Just hold the test set near the building access sensor and the WCT3 will detect the 125 kHz signal. That will help you troubleshoot door access locations that are not working. It gets even better... you can use the WCT3 to test virtually any other 315 MHz, 433 MHz, 125kHz, 20kHz and IR wireless control system to verify generation of a signal. We should rename this "the handy-dandy, universal, wireless remote control tester"!

The WCT3 test set is housed in a compact 2.25" x 4.6" x 9" case and is powered by a standard 9VDC battery. The test set is available as a do-it-yourself hobby kit or factory assembled and tested. For the kit builder, the WCT3 contains both SMT and through-hole components, with 170 solder points. If you're a car dealer, independent service shop, or simply an owner of a newer vehicle with keyless entry, or have wireless entertainment controls you can't afford not to have a WCT3!

WCT3	**Four-Mode Keyless Entry Test Set Kit**	**$59.95**
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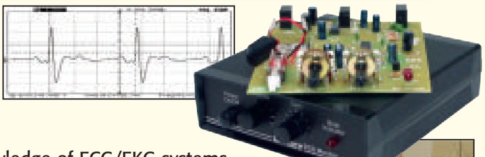
Electrocardiogram ECG Heart Monitor



- ✔ **Visible and audible display of your heart rhythm!**
- ✔ **Bright LED "Beat" indicator for easy viewing!**
- ✔ **Re-usable hospital grade sensors included!**
- ✔ **Monitor output for professional scope display**
- ✔ **Simple and safe 9V battery operation**

Use the ECG1C to astound your physician with your knowledge of ECG/EKG systems. Enjoy learning about the inner workings of the heart while, at the same time, covering the stage-by-stage electronic circuit theory used in the kit to monitor it. The documentation with the ECG1C covers everything from the circuit description of the kit to the circuit description of the heart! Multiple "beat" indicators include a bright front panel LED that flashes with the actions of the heart along with an adjustable level audio speaker output that supports both mono and stereo hook-ups. In addition, a monitor output is provided to connect to any standard oscilloscope to view the traditional style ECG/EKG waveforms just like you see on ER... or in the ER! 10 hospital grade re-usable probe patches are included together with the matching custom case set shown. Safe 9V battery operation.

ECG1C	**Electrocardiogram Heart Monitor Kit With Case & Patches**	**$44.95**
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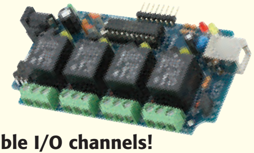

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It is compatible with both Windows and Apple OS X, as well as various Linux flavors. When you plug it into your computer, it appears as a USB CDC device that creates a Virtual Serial (COM) port allowing easy communication with the board through any programming language that supports serial communications (VB, VB.NET, C#, C, C++, Perl, Java, etc).

The controller features four onboard relay outputs with a current rating of 10A each. Also onboard is a 6-channel Input/Output interface, with each channel individually configurable as Digital Input, Digital Output, Analog Input (10-bit Resolution), or DS18B20 series Temperature Sensor. In Digital Input/Output modes, each channel can support a TTL compatible or ST input or a 5V output signal. In Analog Input mode, each channel can convert a voltage of between 0 to 5V into a 10-bit digital representation. Finally, in Temperature Sensor mode, each channel can be connected to a DS18B20 series Digital Temp Sensor.

UK1104 4-Ch USB Relay Interface Kit $59.95

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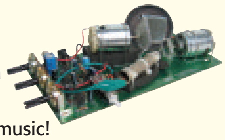

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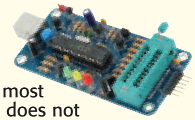

Finally, a compact USB PIC Programmer with a 20 pin ZIF socket for easy programming of most Microchip PIC Flash devices that does not require low voltage programming. Plus it uses USB therefore no more RS232 compatibility blues!

CK1301 USB PIC Programmer Kit $34.95

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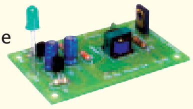

The kit has a pulsing 80 volt tickle output and a mischievous blinking LED. And who can resist a blinking light and an unlabeled switch! Great fun for your desk, "Hey, I told you not to touch!" Runs on 3-6 VDC.

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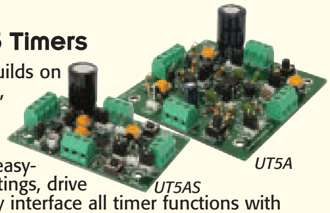

This new series builds on the classic UT5 kit, but takes it to a whole new level! You can configure it on the fly with easy-to-use jumper settings, drive relays, and directly interface all timer functions with onboard controls or external signals.

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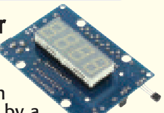

This handy thermometer reads Celsius or Fahrenheit on an eye-catching .56" LED display! Based on the DS18B20 sensor and controlled by a PIC, it has a range of -67°F to 257°F (-55°C to 125°C) with a wired remote range of 325 feet!

CK127 Digital LED Thermometer Kit $29.95

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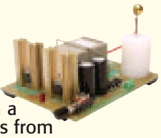

Generate 2" sparks to a handheld screwdriver! Light fluorescent tubes without wires! This plasma generator creates up to 25kV at 20kHz from a solid state circuit! Build plasma bulbs from regular bulbs and more! Runs on 16VAC or 5-24VDC.

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Q&A

WHAT'S UP:

Join us as we delve into the basics of electronics as applied to every day problems, like:

- ✓ Speaker Protector
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- ✓ Remote Control Project

■ WITH RUSSELL KINCAID

In this column, I answer questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist. Feel free to participate with your questions, comments, or suggestions. **Send all questions and comments to:** **Q&A@nutsvolts.com**

SOLAR CONVERTER

Q I was going to try building a solar converter and haven't seen this particular design concept before. My idea was to use 12V solar panels which are readily available for portable construction equipment. Most put out 12 to 16 VDC in moderate to full sun, and are 45 to 75 watts. You run them in series so the DC voltage is between 160 and 190 volts (to exceed the peak voltage of the AC line). Then, take some triacs — or more likely IGBTs — and gate them to the AC line in phase with the incoming voltage. When the solar voltage falls due to clouds or night fall, the IGBTs will turn off and the house reverts to line power. What is your opinion?

— George Bernius

A A 75 watt solar panel will provide 6.25 amps; 6.25A at 120V = 750 watts. I looked at my electric bill and figure I use 1,000 watts daily on average; so 750 watts is not to be sneezed at. If the house is not using 750 watts, the excess will flow through the wattmeter and run it backward; thus saving on the monthly bill.

I talked to the local electric power company, and it will be more expensive to build your own inverter than to buy an approved unit. The inverter that you buy will have to be IEEE/UL approved, and that inverter will have the safety feature that if the outside power goes down, the inverter will shut down within two seconds. That is probably not a feature you would want, but that is the way it has to work.

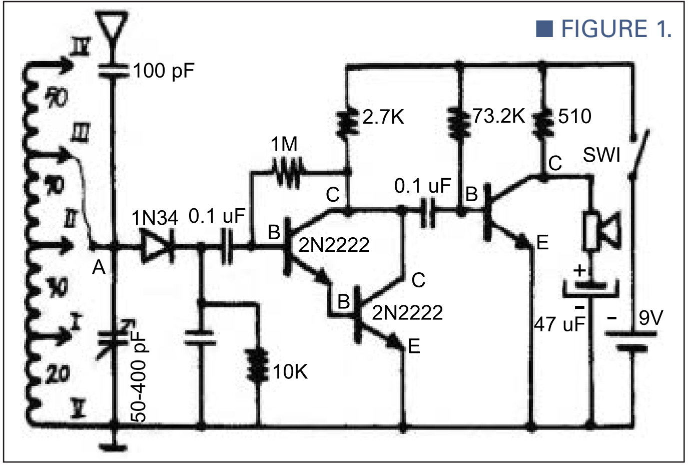
If you go to your power company website, you should be able to download the requirements for generating your own power and connecting to the grid. In New Hampshire, the power company will install a special meter that will keep track of the excess power generated and will "bank it" so you can draw on it later. You can opt for the company to pay you for the excess power, but the rate is low, so it is better to bank it. Check out **www.grid-tie.com/sma.html**.

For a low cost solution, I suggest that you run the DC from the solar system to your electric hot water heater. The hot water heater has two coils: an upper for instant hot water and a lower to heat the entire tank. You can leave the upper connected to AC power for when the sun is not shining and connect the lower to the solar system.

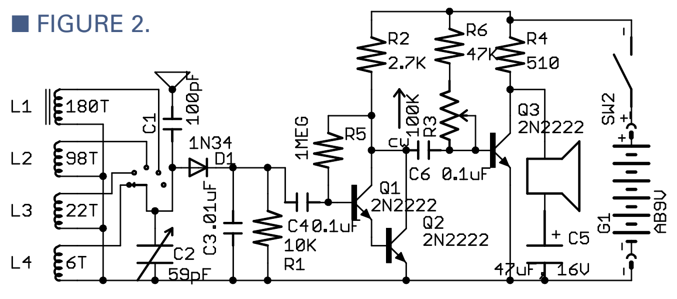
MODIFICATIONS TO A SIMPLE RADIO

Q I have this simple radio that I'd like to build (see **Figure 1**, Ed.). Although I found a variable capacitor rated 0-365 pF on the Internet, I also have two on hand: one rated at 20 pF and another rated at 59 pF. Can you indicate what modifications I should make for each of the two variable capacitors in order to get the most

■ FIGURE 1.



■ FIGURE 2.



MAILBAG

Dear Russell: Re: Photo Transistor Amplifier, Mar '12, page 24/25. In his question "Phototransistor Amplifier," Josh Bensadon asked about the polarity of speaker wires. If there is only one speaker, the polarity does not really matter. If you add a second speaker, then you have a REALLY different animal.

Speakers operate by the magnetic field-produced current flowing in the speaker's voice coil pushing and pulling against the magnetic field of a permanent magnet to move the speaker's diaphragm. The phase of multiple speakers must be the same or there will be some wave interference (cancellation and reinforcement) of the sound pressure waves within the speaker's environment. This interference results in distortion of the sound being broadcast by the speakers.

The same thing happens if multiple microphones do not have the same phase. Microphone connections via the XLR connectors are standardized, so this usually is not a problem. Often, however, someone will inadvertently reverse the phase on a mic connector and will have many headaches trying to find the problem.

— Tim Brown PhD EE, PE

Response: I got a lot of feedback on that, so I think it is pretty well known. Thanks for writing.

Dear Russell: Re: Lithium-ion Battery Charger, Mar '12, page 23. You show the highest rating of SW1 as three amps, and the rating of T1 as 24V @ 3A. T1 will be overloaded when the DC output current is three amps! The current rating of transformers is for a resistive load, where the current is a sine wave in phase with the voltage. In rectifier/filter power supplies, the transformer current is neither a sine wave nor in phase with the voltage. For a full-wave bridge capacitor-input rectifier, the transformer current rating should be 1.8 times the DC output current; in this case, 5.4 amps. (For a full-wave center-tap capacitor-input circuit — as used on page 23, Figure 2 — the DC current should be multiplied by 1.2.)

— Bill Stiles

Response: You are right! I sometimes forget that the I^2**R of pulses is a greater loss than the DC I*R.*

Dear Russell: Re: Lithium-ion Battery Charger, Mar '12, page 23. What is the purpose of the "Legends" Li-ion, NiCAD, NiMH, lead-acid, rechargeable alkaline at the left side of Figure 2?

I may have missed something, but from the description as I read it, the cell voltage will max at four volts although the implication is that it can be adjusted. If I place a 'standard' NiCAD or NiMH cell with a nominal 1.2 volt rating, will this circuit try to charge it to four volts?

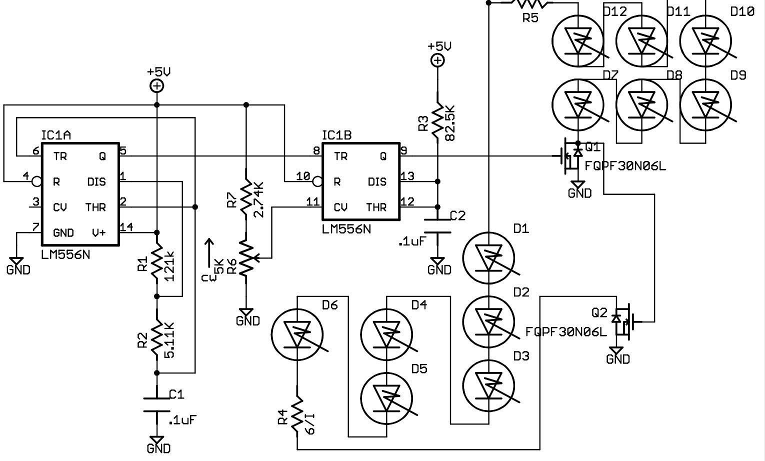
— Ron Hand

Response: Oh, you are right. My bad! I originally intended to have a table of values for the other cell types but ran out of time. This circuit only does Lithium-ion cells, as you deduced.

Dear Russell: Re: LED Dimmer Circuit, Feb '12, page 27. I breadboarded the LED dimmer circuit and all I get from section 1 of the 556 are narrow pulses on my 'scope. Section 2 does not dim the LEDs. I have tried all pot positions but it does not change the pulse width or LED brightness. I have been checking the circuit all afternoon and am sure I have it wired correctly according to the diagram. I even tried several 556 timers. Is there something that I am missing?

— Fred Krauss

Response: You are not missing anything, C2 (.1 µF) is missing from the schematic; my apologies. I simulated the circuit, added R7, and changed the value of R3 for better operation. If the voltage on the CV pin exceeds 3/4 of VCC, the circuit will divide by two which screws up the duty cycle. So, if you find that when R6 is fully CW, the duty cycle suddenly changes, R7 needs to be increased slightly. See ***Figure A****. Thanks for writing.*


■ FIGURE A.

out of it, so I would basically get the recommended 50-400 pF variable capacitor?

— Michael Williams

A My first thought was: 59 pF is not useful; but after doing some calculations, it turns out that only four coils are needed to cover 520 kHz to 68 MHz. The schematic (**Figure 2**) shows a tapped inductor, but I am proposing four separate coils because the small tuning capacitance requires a larger inductance. I basically re-drew the schematic that you sent, but changed R6 by adding a 100K pot because that kind of bias is not stable and will have to be trimmed.

The speaker or earphones should be high impedance; eight ohm units will not work very well. For a speaker, Mouser #254-DR150-RO ($1.36) should work. The minimum capacitance is never zero; I used 5 pF minimum. The low frequency coil will be wound on a ferrite rod, available from **www.Bytemark.com** for $22.95. If I were you, I would try to salvage the loopstick antenna from an old AM radio.

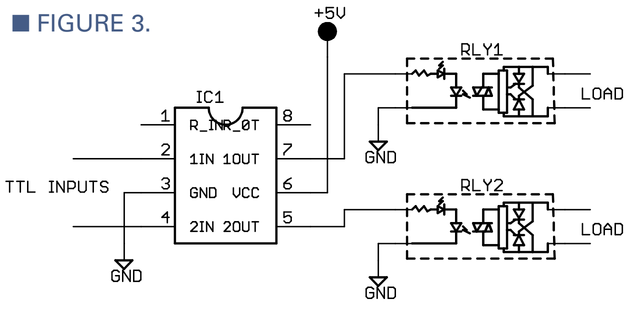
For best results, the coil should be space wound to cover the length specified. For the other coils, I used a small pill bottle 1.275 inches in diameter. The length is adjusted to give an even number of turns. You can stretch or compress the turns to get the frequency range you want, and then anchor the wire with tape. The coils are as follows:

- L1: 520 kHz to 1.78 MHz; 180 turns #30 on ferrite core; R-050750-61, 7.5 inches long.
- L2: 1.7 MHz to 5.84 MHz; 55 turns #30 on ferrite core; R-050750-61, 7.5 inches long.

I think L2 could be a tap on L1, but the number of turns you might need would be greater.

Alternately:

FIGURE 3.



- L2: 1.7 MHz to 5.84 MHz; 98 turns #30 on a 1.275 inch form, 2.1 inches long.
- L3: 5.8 MHz to 19.9 MHz; 22 turns #30 on a 1.275 inch form, 1.0 inches long.
- L4: 20 MHz to 68 MHz; six turns #30 on a 1.275 inch form, 0.8 inches long.

SPEAKER PROTECTOR

Q I'm building a speaker protector for stereo test speakers. In the past, I built my own but due to a time restriction, I decided to purchase two boards.

My question is on the transformer. I have a few choices and I want to do it right. The boards require AC power for each channel.

The requirement is for 12 0 12 VAC. Using a transformer with a CT is an option. The wiring diagram doesn't list the volt amps, so I decided to spec it on the mA current of the relay coil; around 40 mA.

Is there an advantage to using a transformer for each channel? What about using a transformer with a center tap?

I'm kind of leaning toward purchasing four transformers 250 VA 24 VAC with a CT. Is one transformer for each channel overkill?

I thought the easiest thing to do is send you the link to my purchase. I value your opinion and I just want to make sure that I'm buying the correct transformers (**www.ebay.com/itm/260905709010?ssPageName=STRK:MEWNX:IT&_trksid=p3984.m1439.l2649**).

— Jeff Miller

A I got a reply from China; the current requirement is 300 mA, so a transformer of 10 VA is needed. Two Mouser part numbers will fit: #553-F45X which is a flange mount with wires; or #655-4900-9024RD63 which is a PC mount. You could use one 250 VA transformer for both boards, but separate transformers will avoid the possibility of a ground loop. You don't need four transformers; I don't understand the center tap being optional. Either you need it or you don't.

COMPUTER CONTROLLED AC SWITCH

Q I would like to have a circuit to power cycle routers, hubs, and various other devices remotely from my computer. I have a DAQ card which provides enough digital I/O lines to control up to five relays. The relays should be opto-isolated to prevent damage to the DAQ card and to be able to handle 120 VAC at five amps. My idea was to use transistors to switch the relays, but should I use solid-state or mechanical relays? Do you have any other circuit ideas? I am sure your other readers could benefit from this type of circuit also.

— Mike Taber

A Mechanical relays will be cheaper, but a driver and power supply will be needed because five volt relays are hard to find and will require more current than TTL can supply. The solid-state relay will only require a driver, but also dissipates considerable power. With a voltage drop of 1.3 volts at five amps, the power lost is 6.5 watts. I would go with the solid-state relay because it has better reliability and the circuit is simpler.

The TPS12 is a dual non-inverting driver that works at five volts VCC or, TPS15 is a dual inverting NAND driver. For a solid-state relay, Mouser #558-CWD2410 operates with four volt control and switches 0.15A to 10A at 280 VAC max. Triac type AC solid-state relays require a minimum load current for reliable operation. The circuit in **Figure 3** is pretty simple.

REMOTE CONTROL PROJECT

Q I need to learn how to use a TV remote to send a binary value to a computer via the USB. Is there a back issue of *N&V*, or can you point me to a website that documents the steps and hardware needed? I am just starting to learn hardware from reading the magazine, and I have been into software. The article in the Jan '12 issue by Richard Dzjoba gave me the idea, but since I do not have Internet access, I am lost as to hardware.

— Ron Riva

A Every TV remote is different — as you probably know — so you will need to analyze the output of the IR receiver (a storage oscilloscope will be handy) and use a lookup table to convert it to a binary number. Gyration's GYAM5600 RF IR receiver plugs into the USB, so all you need to do is write some software. You could also use a remote keyboard to directly access the PC through the 2.4 GHz RF link. Since you do not have Internet access, I am sending you some screen prints of available hardware. Let me know if you need more help.

TRANSFORMERLESS POWER SUPPLY

Q I need a transformerless power supply and I remember you addressed this issue in the Tech Forum column back in May '04. I liked your reply because it doesn't contain polarized plugs, but I'd like to use it at a different mA value; 12 VDC @ 80 mA and 3 VDC @ 10 mA. Please indicate what modifications I should make to the schematic.

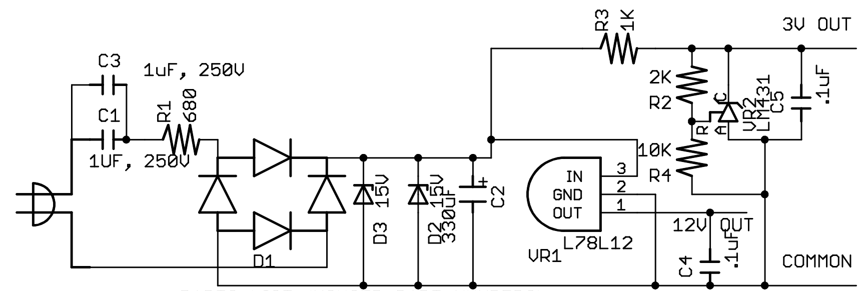
— Anonymous

A polarized plug was not used because no part of the circuit or load can be grounded. The entire circuit and load must be considered live and enclosed such that no one can get their fingers on it.

The revised circuit is shown in **Figure 4**. The total current at the input is 80 mA + 10 mA + zener current = 100 mA. The current limiting impedance (C1, C2, and R1) is calculated as below:

The peak input voltage is:
120*1.41 = 169V
The voltage at the diode bridge is: diode drop + zener voltage = 1V + 15V = 16V
$Z = (Xc^2 + R1^2)^{.5} =$
(169V – 16V)/100 mA
= 1,530 ohms
Squaring to remove the square root: 2.34 meg =
Xc^2 + .462 meg Xc = 1.37K
At 60 Hz, C = 2 µF.

I could not find a 78L03 through hole part nor TL431, so I used an LM431 in a TO-92 package. I doubled up on the zener because if the outputs are not loaded, one zener will have to take all the current which is greater than its rating.


C3
1uF, 250V
C1
1UF, 250V
R1
680
D1
D3
15V
D2
15V
330uF
C2
IN
GND
OUT
3
2
1
VR1
L78L12
R3
1K
2K
R2
10K
R4
R
A
C
VR2
LM431
C5
.1uF
3V OUT
12V OUT
C4
.1uF
COMMON

PARTS LIST (MOUSER PART NUMBERS)

C1, C3	1uF, 250V, 10%	5989-250V1.0-F
C2	330uF, 20%, 25V	75-516D337M025MN6A
C4, C5	.1uF, 10%, 50V, X7R	80-C410C103K5R
R1	680 OHM, 5%, 10W	588-20J680E
R2	2K, 1%, 1/4W	71-CCF55-2K
R3	1K, 5%, 1/4W	71-CCF55-1K
R4	10K, 1%, 1/4W	71-CCF55-10K
D1	1A, 400V, BRIDGE, 4 PIN DIP	625-DF04M
D2, D3	15V, 1WATT	78-1N4744A
VR1	DC REG, TO92, 12V, .1A	511-L78L12ABZ
VR2	DC SHUNT REG, 2.5V ADJ	512-LM431BCZKA

■ FIGURE 4.

REQUEST FOR TRANSFORMER AND HEATSINK INFORMATION

Really appreciated your answer about the LM317T regulator chip in the Mar '12 issue. It was one of the best tutorials I've ever seen on the subject. Would you please expand it just a little to cover the selection of transformers and heatsinks? Transformers come in discrete output voltages. The most common I've seen in the catalogs are six, 12, and 20 volts. If you are building a 12 VDC regulator, can you use a 12 VAC transformer or do you have to go to the 20 VAC model?

Also, is there some rule of thumb for how many square inches of heatsink you need to provide per watt? We can easily calculate the power dissipated in the chip by multiplying the voltage across the chip by the output current. The result could easily get to be several watts. It would seem that the lowest voltage transformer would be advantageous to reduce heating of the chip.

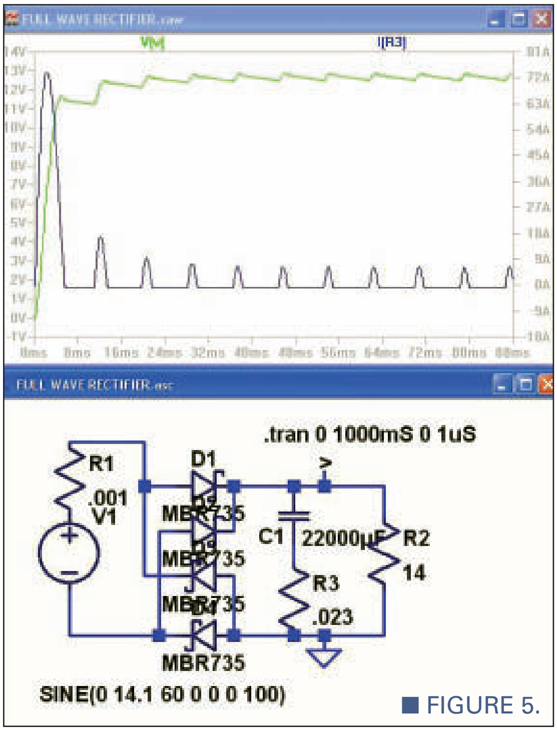
— Don Hicke

You are right that keeping the difference between the rectified output of the transformer and the required input of the regulator low will minimize the power dissipation.

Transformer specs generally don't tell you the regulation, just the output voltage at a specific current. For example: 12.6 VAC @ 1.6A. The no-load output will be higher due to I^2*R and magnetic losses. Since the capacitor charges to the peak of the AC waveform, the rectified output of the 12.6 volt transformer will be about 17 or 18 volts with a 1.6 amp load. The no-load DC output could be as high as 26 volts.

If you wanted 12.6 VDC at one amp and used a 10 VAC transformer rated at one amp, the DC out of the rectifier/filter will be 14.1 volts, and would be enough to run an LDO (low drop-out) regulator. The problem is that the current from the transformer is not DC; it is pulses at the peak of the sinewave.

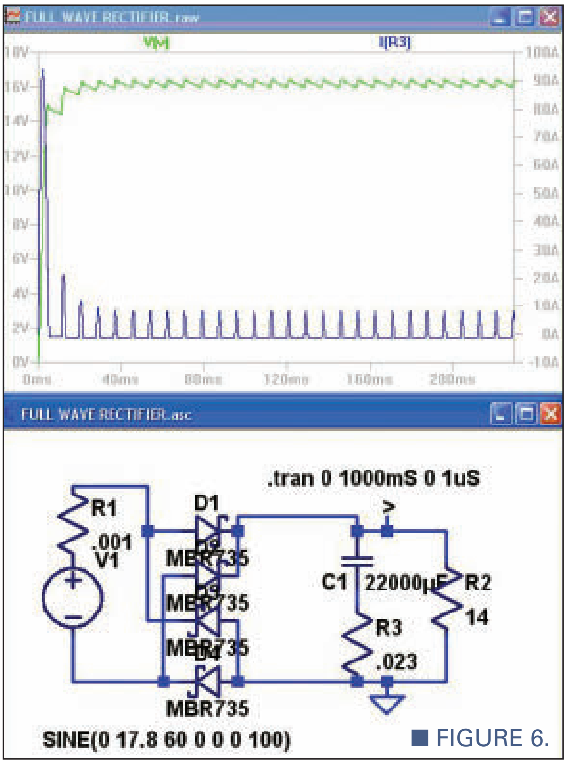
The I^2*R of the pulse is naturally greater than the I*R of DC. If the


FULL WAVE RECTIFIER.raw
V[v]
I(R3)
14V
13V
12V
11V
10V
9V
8V
7V
6V
5V
4V
3V
2V
1V
0V
-1V
81A
72A
63A
54A
45A
36A
27A
18A
9A
0A
-9A
-18A
0ms
8ms
16ms
24ms
32ms
40ms
48ms
56ms
64ms
72ms
80ms
88ms
FULL WAVE RECTIFIER.asc
R1
.001
V1
D1
MBR735
MBR735
MBR735
MBR735
C1
22000µF
R2
14
R3
.023
>

.tran 0 1000mS 0 1uS

SINE(0 14.1 60 0 0 0 100)

■ FIGURE 5.


FULL WAVE RECTIFIER.raw
V[v]
I[R3]
18V
16V
14V
12V
10V
8V
6V
4V
2V
0V
100A
90A
80A
70A
60A
50A
40A
30A
20A
10A
0A
-10A
0ms
40ms
80ms
120ms
160ms
200ms
FULL WAVE RECTIFIER.asc
.tran 0 1000mS 0 1uS
R1
.001
V1
D1
MBR735
MBR735
MBR735
MBR735
C1
22000µF
R2
14
R3
.023
SINE(0 17.8 60 0 0 0 100)

■ FIGURE 6.

transformer is conservatively designed, that may not matter. To be safe, however, choose a higher rated transformer. The next higher rating is two amps, and the size and cost of the two amp transformer is the same as the 12.6 VAC, 1.6A transformer in this case, but the power is less. See **Figure 5** for an analysis using LTspice.

You will need a filter capacitor to keep the ripple voltage under one volt peak/peak or else the LDO will run out of head room. The capacitor is charged to peak voltage every 8.3 milliseconds and must supply the one amp load in the meantime. Choose a ripple of 0.5 volts peak to peak; the filter cap is then computed from:

dV/dT = I/C

C = I*dT/dV = one amp*8.3 mS/.5V = 17 mF = 17,000 µF

Use the next higher standard value: 22 mF. This capacitor (Mouser #661-ESMH250VNN223MR) has an ESR (Equivalent Series Resistance) of .023 ohms and you can see in **Figure 5** it has a considerable effect on ripple voltage.

In **Figure 5**, the bottom of the ripple is near 12 volts, so my calculation was not sufficiently conservative. I have to go to the 12.6 volt transformer, rated at 1.6 amps. Note that in **Figure 5**, the first pulse is over 70 amps. That is a good reason to use an inrush current limiter and a reason that slo-blo fuses are needed.

Figure 6 is the same circuit with the 12 volt transformer. The bottom of the ripple voltage is about 16 volts, so there is plenty of headroom for the LDO. The ripple is 0.5 volts and part of that is due to the nine amp current pulse flowing through the 0.023 ohm ESR.

One way of reducing the amplitude of the current pulses is to

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put an inductor between the rectifier and the filter cap. This was routinely done in the vacuum tube era, and the inductance was in henries.

A smaller inductance can make a big difference, however. In **Figure 7**, a 1 mH inductor is introduced and the peak inrush current is reduced from 90 amps to 50 amps; the steady state current pulses are three amps instead of nine amps. The ripple voltage is much lower, and the DC voltage is about one volt lower.

Commercial heatsinks are rated in degrees C per watt. If your transistor is dissipating five watts and you want to limit the temperature rise to 25 deg C, choose a heatsink rated 5 deg C/watt or lower. If you want to make your own out of sheet aluminum, I didn't find a rule of thumb on the Internet, so I made some measurements.

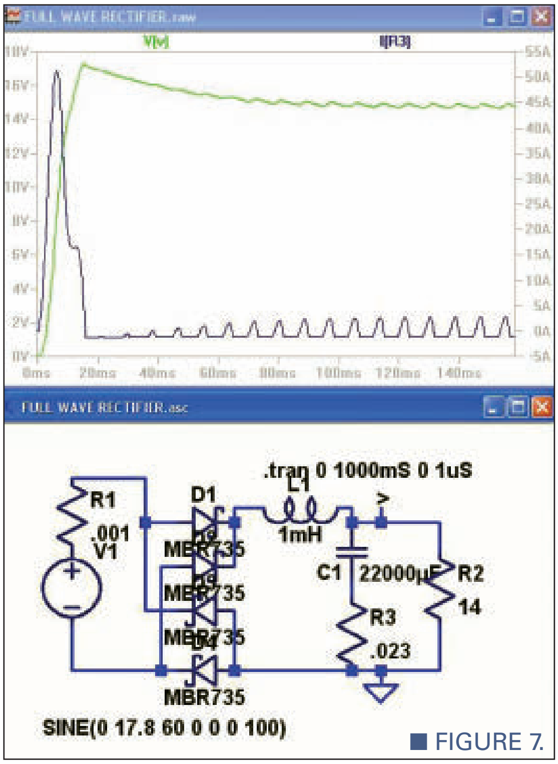
A thick sheet will have more thermal lag (the time it takes to reach thermal equilibrium), but the final temperature will depend on the surface area. If the sheet is vertical, you can count both sides. If it is horizontal — to be safe — only count the upper side. My test used 1/8 inch thick aluminum held vertically with an aluminum-cased resistor (rated 30 watts) mounted in the middle. The results are shown in **Table 1**.

You can see the data is non-linear, but with only three data points. I can't draw a good curve.

Also, the resistor area is a larger part of the 2 x 4 sheet than the 7.4 x 11.5 sheet, so that skews the data. **NV**

Heatsink size (inches)	Watts	Temperature rise deg C
2 x 4	14	60
5.6 x 9	28	60
7.4 x 11.5	31	60

Table 1.


FULL WAVE RECTIFIER.raw
V(n)
I(R3)
18V
16V
14V
12V
10V
8V
6V
4V
2V
0V
55A
50A
45A
40A
35A
30A
25A
20A
15A
10A
5A
0A
-5A
0ms
20ms
40ms
60ms
80ms
100ms
120ms
140ms
FULL WAVE RECTIFIER.asc
.tran 0 1000mS 0 1uS
R1
.001
V1
D1
MBR735
MBR735
MBR735
MBR735
L1
1mH
C1
22000µF
R2
14
R3
.023
SINE(0 17.8 60 0 0 0 100)

■ FIGURE 7.

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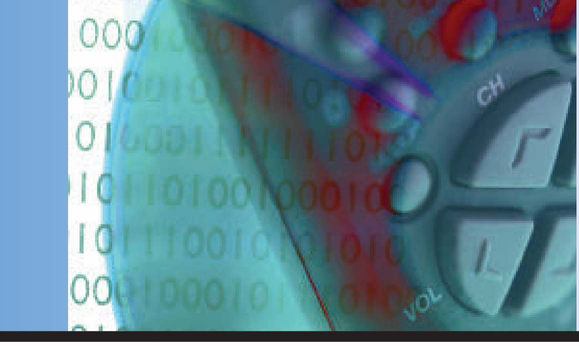

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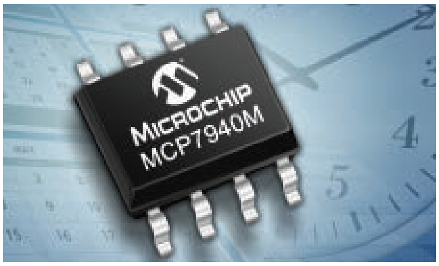
Microchip Technology, Inc., announces the expansion of its stand-alone Real Time Clock/Calendar (RTCC) family with the I^{2}C™ MCP7940M RTCC device.

This new device is designed for the price-competitive consumer products market, and includes 64 bytes of SRAM as additional scratchpad memory, as well as a digital trimming circuit that can compensate up to 11 seconds per day for crystal error. The MCP7940M devices provide accurate timekeeping at a low cost for applications in home appliances (e.g., microwaves, washing machines, dryers, ovens, thermostats); audio/video (e.g., radios, televisions, set-top boxes, digital recorders); and consumer electronic markets (e.g., printers, network routers, cameras), among others.

The MCP7940M device has a simple feature set that meets the needs of the high volume segment of



the RTCC device market. Microchip now has stand-alone RTCC devices for the low-, mid-, and upper-mid ranges of this market. The on-chip digital trimming circuit has a wide trimming range of ±127 PPM, enabling users to select lower quality crystals for their designs to reduce overall system costs.

The MCP7940M RTCC is available in eight-pin MSOP, PDIP, SOIC, TSSOP, and 2 mm x 3 mm TDFN packages.

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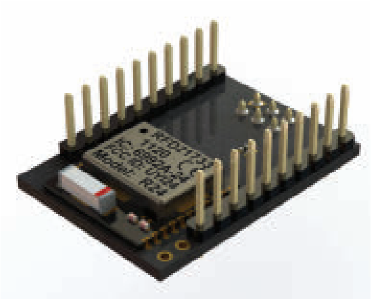
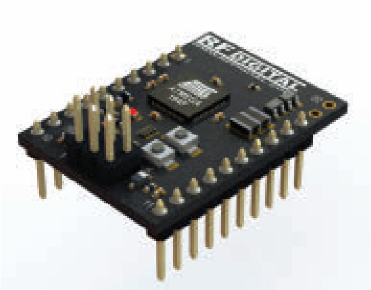
There's no need for additional





development tools or special connectors. No wiring or soldering is needed and RF knowledge is not necessary. You can reuse existing code, and there is no need to fabricate PCBs. All bypass caps are included and the modules plug into any breadboard. They are also compliance approved and fully tested.

Sample code is supplied for Atmel, Microchip, Texas Instruments, and Silicon Labs controllers.

Users simply output serial bytes (using their favorite controller) and the module takes care of the rest. It will seamlessly transfer data over the air up to 500 feet (150 meters).

For more information, contact:
RF Digital
Web: **www.rfdigital.com**

AFFORDABLE PROTOTYPING 3D PRINTER

Saelig Company, Inc., announces the availability of the Replicator™ — an affordable, personal 3D printer offering one- or two-color "printing" of solid objects. The Replicator runs open source 3D printing code and is compact enough to fit on a desktop. Ready within minutes to start printing right out of the box, the Replicator fabricator turns raw feedstock — such as ABS or PLA — into instant prototypes as large as a loaf of bread.

The Replicator is a precision-made parts fabricator built with linear ball bearings and precision-ground 8 mm shafts. It's ideal for personalized manufacturing or prototyping, providing a new way to fabricate designs and variants quickly, as large as 225 x145 x150 mm (8.9" x 5.7" x 5.9"). The Replicator is available with single or dual extruders, facilitating simultaneous two-color printing.

The Replicator
MakerBot
Saelig

The Replicator features a 4x20 character LCD panel and multi-directional control pad. The LCD screen provides build data as well as monitoring information, and full machine control is possible without the use of a computer.

Using an SD card slot or USB connection, model designs can be loaded and built directly from control pad commands. Professional engineers can now quickly fabricate solid objects using tools like AutoCAD and SolidWorks, producing STL or gcode files. ReplicatorG software provided (Linux, Windows, and OSX compatible) enables rapid prototype production.

Layer thickness may be selected from 0.2-0.3 mm with the stock 0.4 mm nozzle; parts are built at a speed of 40 mm/s, with positioning precision of 2.5 microns (Z axis) and 11 microns (X-Y axes).

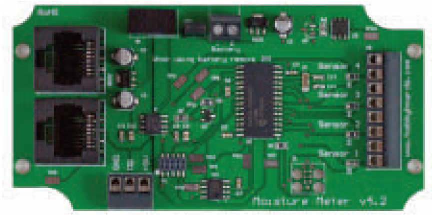
Sized for almost any desktop (320 x 467 x 381 mm; 12.6" x 18.4" x 15"), the Replicator weighs 26-29 lbs (single/dual).

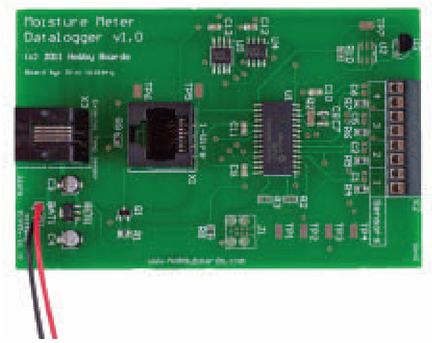
For more information, contact:
Saelig
Web: **www.saelig.com**

MOISTURE METERS AND DATALOGGER

Hobby Boards has recently launched two new moisture meters, expanding their range of high quality, affordable weather and environment monitoring equipment.

The redesigned moisture meter ($62.50) replaces their earlier 1-Wire board design. This board reads input from Watermark soil sensors and leaf wetness sensors, and is designed to connect directly to a 1-Wire network. Enhanced features include calibrated readings from up to four Watermark soil sensors (with a range of 0-199 centibars) and/or leaf wetness sensors (with readings from 0-100% wet), as well as field-upgradeable firmware.





Also newly introduced is Hobby Boards' moisture meter datalogger ($85.00). Designed at the request of an agricultural customer, the datalogger can be installed at remote locations and will read data from soil sensors and/or leaf wetness sensors at user-specified intervals, logging results to Flash storage. With low power usage for months of logging, 1 MB of Flash storage for thousands of data records, and using readily-available AA batteries, this practical device greatly expands moisture monitoring capabilities.

Like the moisture meter, the datalogger version supports up to four sensors and has field-upgradable firmware. It additionally features an onboard temperature sensor, and supports an additional external temperature sensor if desired. The datalogger connects to a 1-Wire master for setup and log retrieval.

For more information, contact:
Hobby Boards
Web: **www.hobbyboards.com**

THOUGHT-PROVOKING ESP LAMP

The ESP Lamp from Images Co. is a thought-provoking tool that allows the user to perform their own PSI experiments. The lab quality Random Number Generator (RNG) inside the ESP lamp provides a platform to test and verify current research results found in parapsychology journals and texts.

The ESP lamp provides an ESP/PSI testing platform. The heart of the RNG is a miniature Geiger counter whose detection of radioactive particles triggers the generation of true random numbers. Each random number generated will light one of four different color LEDs: red, green, blue, and yellow. While this setup might appear trivial, it is not. True random numbers may be used to accurately test for different aspects of ESP.

ESP Lamp Applications

Precognition: Predict the color of the LED that will light next and track the results.

Psychokinesis (PK): Use your mind to influence the color output from the ESP lamp.

Telepathy: Two people are in separate rooms; one is a sender, the other is a receiver. The sender observes the ESP lamp and tries to transmit the color changes when they occur to the receiver.

Fortune Telling: Use the random color generated to indicate answers to questions.

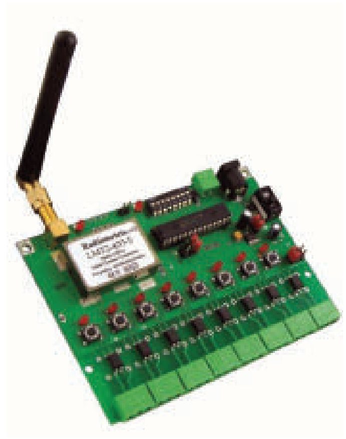
Mood Lamp: The changing LED color output of the ESP lamp is unpredictable both in time and color. You can look at it as a sophisticated mood lamp.

Radioactive Fallout Detector: Since the ESP lamp has a built-in Geiger counter, excessive radiation (from radioactive fallout) would cause the LEDs to blink rapidly.

For more information, contact:
Images Co.
Web: **www.imagesco.com**

CTA28 APP BOARDS

The CTA88 chip from Lemos International is a simple encoder/decoder for use with ISM band telemetry modules. It permits a simple, one-way wireless link to be established for simple remote control applications, with a minimum of effort and no customer software input.



These TX and RX application boards are designed to allow easy evaluation of the CTA88 device in elementary jobs. They provide simple two-channel implementations, using either LMT/LMR or BiM footprint radio modules.

The CTA28 app board features an eight-bit address and two-bit data select switches. It offers two relays to control mains powered devices rated up to 8A 250 VAC/30 VDC, and has a visual indication of valid code received and active relays. It has RF module range testing, a pushbutton for momentary control of relays, momentary latched outputs, dynamic relay state changes, and setup is plug-and-play with RF remote control demonstrations.

Ideal applications for the CTA28 app boards are wireless security and alarm systems, emergency assistance call systems, status reporting, and monitoring systems, along with RF remote control systems. They can also be used for industrial controls, HVAC controls, simple on/off switching, and long range telecontrol with narrow band FM radios.

For more information, contact:
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Cornell Dubilier Electronics, Inc., announces the release of Type CDLC, CarbonCap double layer capacitors, and Type CDHC hybrid ultracapacitors. Cornell Dubilier's lineup of large cell cylindrical ultracapacitors spans 1,200 to 3,000 farads, snap-in style ultracapacitors from 100 to 600 farads, and higher energy hybrid capacitors from 220 to 1,000 farads.

CDHC hybrid capacitors are half ultracapacitor and half Lithium-ion battery. These hybrid capacitors store more than twice the energy of typical ultracapacitors and have high cycle life capability compared to batteries. Hybrid capacitors have more power than Lithium-ion batteries, but less energy storage.

By comparison, ultracapacitors have a cycle life capability of a million cycles or more; batteries have a cycle life of around 1,000 cycles; and hybrid capacitors, more than 20,000 cycles. While the ultracapacitors have a usual working voltage range of 1.3V to 2.7V, hybrid capacitors operate from 1.0V to 2.3V. The higher energy of hybrid capacitors makes them especially suitable for use in LED lighting and emergency pulse applications (e.g., operation of electric doors and windows).

Type CDLC CarbonCap ultracapacitor cells are available with axial, M12 threaded mounting studs on both ends, as well as additional mounting options. The new snap-in units are available in two- and four-pin versions, and are well suited for wind turbine blade pitch control.

The large ultracapacitors handle back-up and pulse power applications such as grid stabilization. They also excel in transportation applications like automotive subsystems, rail system power, and utility vehicles. They provide extended power allowing critical information and functions to remain available during dips, sags, and outages in the main power source.

These cells can relieve batteries of burst power functions, thereby reducing costs and maximizing space

Continued on page 77

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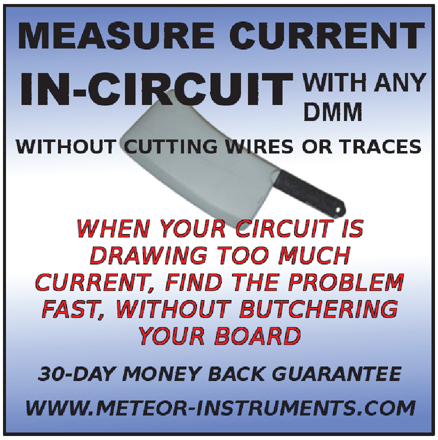

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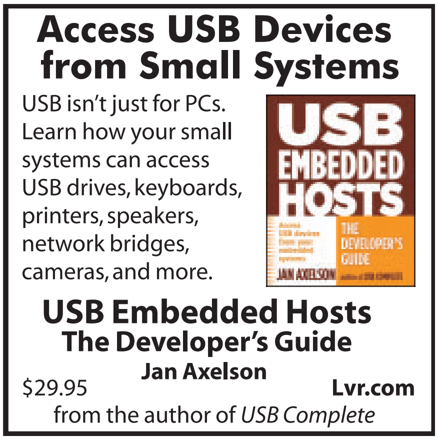

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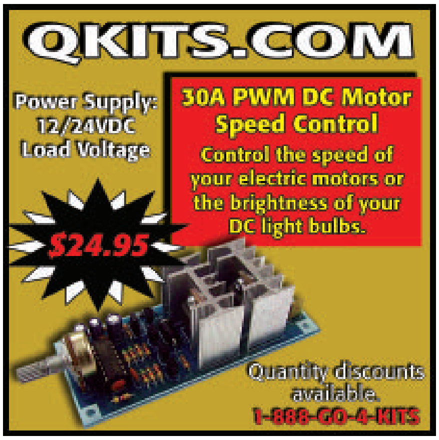

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Cracking PDF File Passwords With a BeagleBone Board

By Nuno Alves

www.nutsvolts.com/index.php?/magazine/article/june2012_Alves
Discuss this article in the Nuts & Volts forums at http://forum.nutsvolts.com.

I am a strong proponent of customized embedded systems aimed at performing a single task. If we have a software program that is time-intensive, difficult to run, and a mess to configure, I believe it is probably best to execute it in a customized "single-serving" system. For example, let's say we have an encrypted PDF file and we are trying to figure out its password. A quick Google search provides us with plenty of downloadable programs — some even free — that promise us the desired outcome. Is downloading and installing a third party tool the best approach? Hardly.

In general, I am very wary of installing software in my computer, even if I have access to its source code. Who knows what is happening behind the scenes, deep inside some obscure assembly function. Sure, the program may be trying to find the password for my encrypted PDF file, but at the same time it may be sending all my computer passwords and credit card numbers to some shady folks. Even if the password cracking program comes from a "reputable" software house, installing software always leaves something extra behind which inevitably bloats our hard disks and slows down our systems.

Instead of installing a piece of software on my PC, I wondered if I could crack a PDF file password using an inexpensive off-the-shelf embedded system not connected to any computer. My system of choice was BeagleBone.

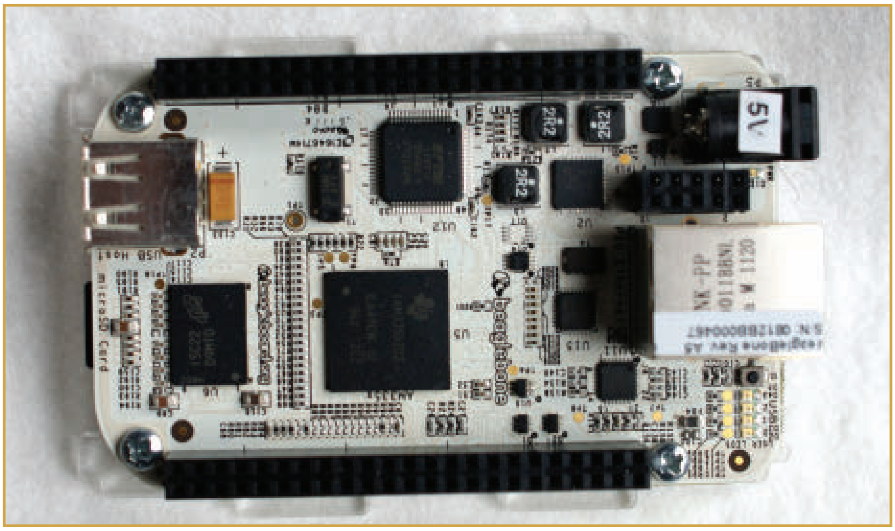


FIGURE 1. Top view of the BeagleBone.

BeagleBone?

The BeagleBone shown in **Figure 1** is a new low power open source hardware single-board computer developed by Texas Instruments (TI). The internals of this $85 embedded system are impressive: an OMAP3530 processor running at 720 MHz, 256 MB of RAM, two 46-pin expansion connectors, on-chip Ethernet, a microSD slot, and a USB host port. Some of the pins in Expansion

A and Expansion B are General Purpose Input Output (GPIO), which means they can be controlled to suit our needs. For example, we can use them to read inputs from buttons, drive LCD screens, or even blink LEDs. In essence, the BeagleBone is a compact and powerful Linux compatible computer with embedded characteristics.

Before trying to replicate this project on your own BeagleBone board, I recommend reading the introductory BeagleBoard article by Jan Axelson in the April '12 issue of *Nuts & Volts*, as well as the "Getting Started" guide that is included in the retail box with your BeagleBone. Henceforth, I assume you have the know-how to send files from a desktop computer to the BeagleBone, and to run Linux commands from the BeagleBone command line.

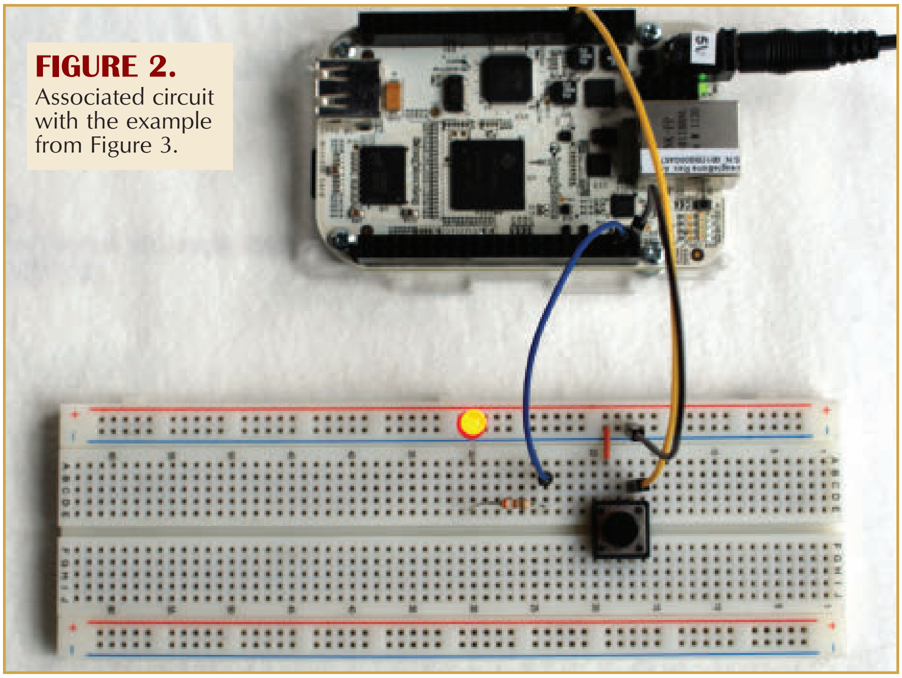


FIGURE 2. Associated circuit with the example from Figure 3.

Control an LED With a Pushbutton

Before implementing a PDF file cracker, it is necessary to learn how to interact with the GPIO pins. In this first experiment, I describe how to control the state of an LED with a pushbutton. Make sure you do **not** skip this first experiment, as without it nothing else in this article will work. The first step is to attach a USB cable from your computer to the BeagleBone USB client port. Download the file **www.nunoalves.com/source/beagle_io.tar.gz** and place it in any directory inside your BeagleBone.

This file contains the source code of two useful libraries (together with some examples written by myself) which dramatically simplify GPIO pin control in C. In your BeagleBone command line, navigate to the directory where the `beagle_io.tar.gz` is located and extract the BeagleBone I/O library with the following command:

```
tar -xvf BeagleBone_io.tar.gz
```

To assemble the suggested prototype circuit, connect a pushbutton between P9_12 and ground. The P9_12 GPIO pin when used as an input has an internal pull-up resistor, hence the need to ensure the pushbutton is connected to ground when pressed. Secondly, a 100Ω resistor must be added in series with an LED between P8_3 and ground. Since GPIO pins have an output voltage of 3.3V, the 100Ω is enough to guarantee reasonable current through the LED. This circuit is shown in **Figure 2**.

Using the built-in Linux editor *nano*, create a new C file and type the code in **Figure 3** (e.g., `nano led_on_off.c`). To compile and run your code, return to the command line and type:

```
gcc -c BeagleBone_gpio.c
gcc BeagleBone_gpio.o led_on_off.c -o
myLED_program
./myLED_program
```

The `BeagleBone_gpio.h` library has many useful functions. One of these is `pinMode` which sets the GPIO pin mode to either output or input. The function `digitalRead` reads the digital value and `digitalWrite` writes a digital value to a GPIO. The `cleanup_GPIO` function is used to tell the operating system that the program is done using the specified GPIO pins.

```
#include "BeagleBone_gpio.h"

int main()
{
            int i;
            struct gpioID LED1,BUTTON1;

            pinMode(&LED1,P8_3,"out");
            pinMode(&BUTTON1,P9_12,"in");

            for (i=0;i<10;i++)
            {
               if (digitalRead(BUTTON1)==1)
                   digitalWrite(LED1,1);
               else
                   digitalWrite(LED1,0);
               sleep(1);
            }

            cleanup_GPIO(LED1);
            cleanup_GPIO(BUTTON1);

            return 1;
}
```

FIGURE 3. This C program executes for 10 seconds, waiting for the user to press the button on P9_12. When the digitalRead function detects a button press, it will send the value of 1 to the digitalWrite function, turning on the LED connected to pin P8_3.

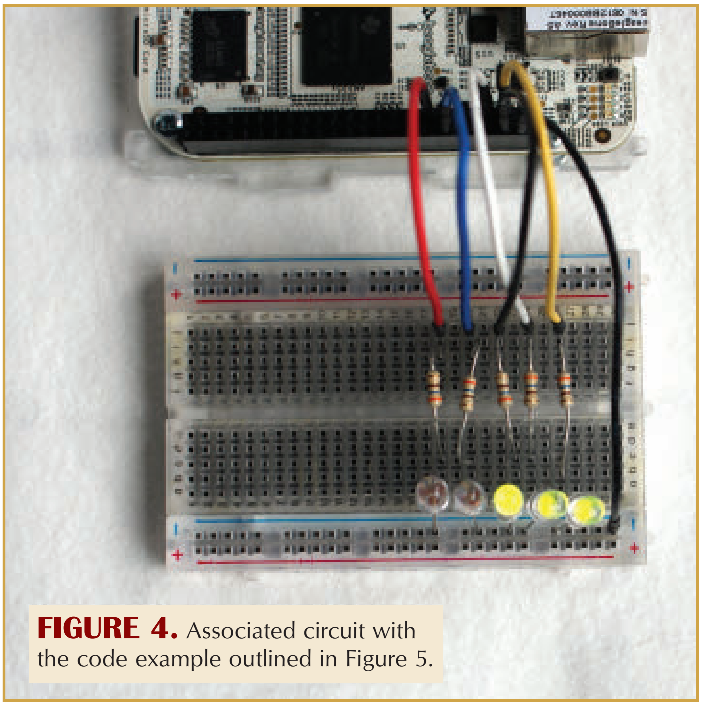


FIGURE 4. Associated circuit with the code example outlined in Figure 5.

Functions for Controlling Multiple GPIOs and Pulse Pins

With the provided library, controlling multiple LEDs is not much harder. For this second experiment, place five distinct LEDs in serial with a 100Ω resistor; each pair is connected to pins P8_3, P8_4, P8_5, P8_11, and P8_12 as shown in **Figure 4**. The code in **Figure 5** shows how to select which pins you would like to turn on. It requires you to convert the binary position of the selected pins in the `pinID[]` array from binary into decimal. For example, the positions for pins P8_3 and P8_5 are 0 and 2, respectively. Converting these two binary positions into a decimal value is $2^0 + 2^2 = 5$. The variable `data_to_write` containing this decimal representation is then used as a parameter to the `digitalWrite_multiple` function which controls the respective LEDs.

As the name indicates, the `delayms` function halts the program execution for a certain number of milliseconds. Finally, `pulsePin` pulses a logic value (initially high, then low) in a particular pin. The fourth parameter on this `pulsePin` function is the pin position in the `pinID[]` array (e.g., P8_4 is pin number 1), while the last parameter (e.g., 1000). is the pulse delay in milliseconds. The two pulsing lines in **Figure 5** blink the connected LED twice, for a period of one second.

Using an HD44780 Compatible LCD Display

The goal of this project is to assemble a stand-alone prototype. This means we need to find another way to visualize data from the BeagleBone without it being connected to a computer through a USB cable. My choice: an Hitachi HD44780 compatible LCD. I am a big fan of these screens, mainly because they are extremely cheap, widely available, and easy to program. In fact, displaying data on a HD44780 can be done by sending carefully chosen bits to each of the LCD screen inputs just using SPDT switches[1].

In this section, I'll describe the steps necessary to integrate a HD44780 LCD with the BeagleBone board. First of all, you need a display. From my Arduino days, I had a couple of them laying around my lab; in particular, I used the fairly inexpensive Microtivity LCD module 1602. Because this LCD requires a 5V source and the BeagleBone GPIO pins only provide 3.3V, you need to get power from other sources. Either connect a 5V DC adapter to the BeagleBone and use P9_5 which provides +5V, or use any external adapter to deliver the appropriate voltage with the help of a voltage regulator.

```
#include "BeagleBone_gpio.h"
int main()
{
    int pinID[]={P8_3,P8_4,P8_5,P8_11,P8_12};

    int nbr_selectedPins=sizeof(pinID)/sizeof(*pinID);
    struct gpioID selectedPins[nbr_selectedPins];
    pinMode_multiple(selectedPins,pinID,nbr_selectedPins,"out");

    unsigned int data_to_write;

    //turning ON P8_3 and P8_5
    data_to_write=5;
    digitalWrite_multiple(selectedPins,nbr_selectedPins,data_to_write);
    delayms(2000);

    //pulse pin P8_4 twice with 1 second delay
    pulsePin(selectedPins,data_to_write,nbr_selectedPins,1,1000);
    pulsePin(selectedPins,data_to_write,nbr_selectedPins,1,1000);

    cleanup_multiple(selectedPins,nbr_selectedPins);

    return 1;
}
```

FIGURE 5. Controlling multiple GPIO pins with a single function: digitalWrite_multiple.

If you opt for the voltage regulator route, I recommend using the breadboard power supply 5V/3.3V kit from SparkFun (PRT-00114). Don't forget to ensure the ground of your external voltage supply is connected to the ground pin (P8_1) of the BeagleBone. Of course, you can bypass all these problems by getting a +3.3V LCD display, which unfortunately tend to be pricier.

Once you have acquired the LCD, establish the connections shown in **Table 1**.

The code in **Figure 6** demonstrates how to print a simple message to the LCD display. Save this code on a file (e.g., `nano test_HD44780.c`) and type the following four commands to compile and run this example:

```
gcc -c BeagleBone_gpio.o
gcc -c BeagleBone_hd44780.o
gcc BeagleBone_gpio.o BeagleBone_hd44780.o
      test_HD44780.c -o myProgram
./myProgram
```

PDF File Cracking Software

Now that I've introduced basic I/O with the BeagleBone, let's focus on the PDF file cracking part. For this design, I would like to have a stand-alone box with an LCD display and a button. I would like the user to insert a USB disk with the encrypted file and press a button to see it being decrypted in real time. This box is to run until the PDF file password has been found.

The first step is to acquire a program that searches for all possible alpha-numeric combinations and see if a specific key is the correct PDF file password. In technical lingo, this type of exhaustive decryption method is called brute-force attack. Through Google, I reached the open source project "PDFCrack - A Password Recovery Tool for PDF Files" (**http://pdfcrack.sourceforge.net**) which does exactly what I was looking for. To run this program in the BeagleBone, follow these steps:

1) Create or obtain an encrypted PDF file and place it on a USB disk. For convenience, the following encrypted file — **www.nunoalves.com/source/encrypted.pdf** — is available online with "meta" as its password.

2) From the project website, download the file `pdfcrack-0.11.tar.gz`.

3) Place `pdfcrack-0.11.tar.gz` on some directory inside the BeagleBoard. Build and uncompress it with the following commands:

```
tar -xvf pdfcrack-0.11.tar.gz
cd pdfcrack-0.11
make
```

4) Insert the USB disk with the encrypted file into the BeagleBone.

5) In order for you to read the contents of a USB disk, first you need to mount it into a Linux directory (e.g., `/mnt/usbdisk`). This can be done with the commands:

```
mkdir -p /mnt/usbdisk
mount /dev/sda1 /mnt/usbdisk
```

6) To start cracking the encrypted file, run the executable `pdfcrack` with:

```
./pdfcrack /mnt/usbdisk/
encrypted.pdf
```

Figure 7 shows the output of each of these steps.

7) Once you are done cracking the password, you must unmount the USB disk before you remove it. Failure to do so may damage the file contents.

```
umount /dev/sda1
```

Attaching the Hardware

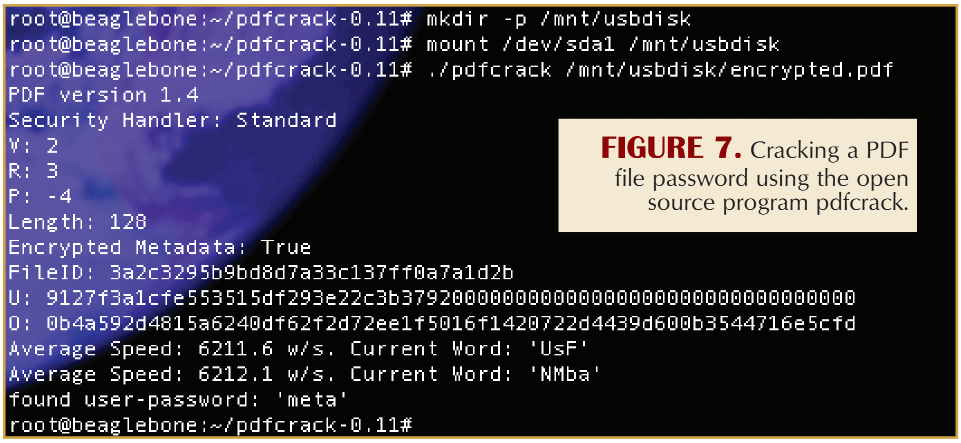
Now that we know how to run the pdfCrack program to brute-force passwords, we need to modify it such that we can start the program with a button and visualize the

LCD Pin #	LCD Pin Description	LCD Pin Connects to
1	VSS	Ground
2	VDD	+5V
3	VO	Adjust contrast with a potentiometer
4	Register Select (RS)	BeagleBone pin P8_4
5	Read/Write (R/W)	Ground
6	Clock Enable (E)	BeagleBone pin P8_3
7	Data Bit 0	Unconnected
8	Data Bit 1	Unconnected
9	Data Bit 2	Unconnected
10	Data Bit 3	Unconnected
11	Data Bit 4	BeagleBone pin P8_5
12	Data Bit 5	BeagleBone pin P8_11
13	Data Bit 6	BeagleBone pin P8_12
14	Data Bit 7	BeagleBone pin P8_14
15	Backlight Anode (+)	+5V (or lower)
16	Backlight Cathode (-)	Ground

TABLE 1.

```
#include "BeagleBone_gpio.h"
#include "BeagleBone_hd44780.h"

int main()
{
     //specifies the pins that will be used
     int selectedPins[]={P8_14,P8_12,P8_11,P8_5,P8_4,P8_3};

     struct gpioID enabled_gpio[6];

     initialize_Screen(enabled_gpio,selectedPins);

     //clear screen
     clear_Screen(enabled_gpio);

     //types "hi" to the screen
     stringToScreen("hi",enabled_gpio);

     //enable blinking cursor
     enableBlinkingCursor(enabled_gpio);

     //types " there"
     stringToScreen(" there",enabled_gpio);

     //wait for 3 second and disable blinking cursor
     sleep(3);
     disableBlinkingCursor(enabled_gpio);

     //don't forget to terminate the screen... or you may get
     terminate_Screen(enabled_gpio,selectedPins);

     return 1;
}
```

FIGURE 6. Interfacing the HD44780 with the BeagleBone.



```
root@beaglebone:~/pdfcrack-0.11# mkdir -p /mnt/usbdisk
root@beaglebone:~/pdfcrack-0.11# mount /dev/sda1 /mnt/usbdisk
root@beaglebone:~/pdfcrack-0.11# ./pdfcrack /mnt/usbdisk/encrypted.pdf
PDF version 1.4
Security Handler: Standard
V: 2
R: 3
P: -4
Length: 128
Encrypted Metadata: True
FileID: 3a2c3295b9bd8d7a33c137ff0a7a1d2b
U: 9127f3a1cfe553515df293e22c3b379200000000000000000000000000000000
O: 0b4a592d4815a6240df62f2d72ee1f5016f1420722d4439d600b3544716e5cfd
Average Speed: 6211.6 w/s. Current Word: 'UsF'
Average Speed: 6212.1 w/s. Current Word: 'NMba'
found user-password: 'meta'
root@beaglebone:~/pdfcrack-0.11#
```

FIGURE 7. Cracking a PDF file password using the open source program pdfcrack.

progress on an HD44780 LCD. The first step is to create a new program that will call pdfCrack when a button is pressed. First of all, ensure that both the libraries from `beagle_io.tar.gz` and the entire source code from pdfCrack are on the same directory. Then, type a C program such as the one in **Figure 8** and save it to a file (e.g., `mycrack.c`). In the first lines of this code, a button and an LCD screen are both initialized. When the program reaches the loop `while(cracked_password==0)`, it waits for a button to be pressed. When it is pressed, the program will issue a system call that will *mount* the USB disk, call pdfCrack, and after the cracking process is complete, *unmount* the USB disk following yet another button press. While the code in **Figure 8** works as expected, the pdfCrack program only displays the cracking outcome to a computer terminal and not to an external LCD screen. This means some slight modifications to the pdfCrack source are in order. By now, you may have realized that there are many files that make up the pdfCrack source code. If you look inside the file *pdfcrack.c*, you will realize that there are two functions that need to be modified. These are `bool printProgress(void)` which reports how many passwords are being cracked per second, and `static void foundPassword (void)` which outputs the correct password that will decrypt the PDF file. For the sake of readability, **Figure 9** only outlines the required modifications on one of these two functions.

```
#include "BeagleBone_gpio.h"
#include "BeagleBone_hd44780.h"

int main()
{
    int cracked_password=0;
    struct gpioID BUTTON1;
    pinMode(&BUTTON1,P9_12,"in");

    //specifies the pins that will be used on the LCD screen
    int selectedPins[]={P8_14,P8_12,P8_11,P8_5,P8_4,P8_3};

    struct gpioID enabled_gpio[6];
    initialize_Screen(enabled_gpio,selectedPins);
    clear_Screen(enabled_gpio);

    stringToScreen("Insert USB disk",enabled_gpio);
    goto_ScreenLine(1,enabled_gpio);
    stringToScreen("and press button",enabled_gpio);

    terminate_Screen(enabled_gpio,selectedPins);

    //Loop while the password hasn't been cracked
    while(cracked_password==0)
    {

        //if button was pressed, make many system calls that
        //will mount the disk and start the cracking process
        if (digitalRead(BUTTON1)==0)
        {
                system("mkdir -p /mnt/usbdisk");
                system("mount /dev/sda1 /mnt/usbdisk");
                system("./pdfcrack /mnt/usbdisk/encrypted.pdf");
                system("umount /dev/sda1");

                cracked_password=1;
                //after cracking is done, wait here until
                //the user presses the button again...
                while(digitalRead(BUTTON1)==0){};
        }
    }

    cleanup(BUTTON1);

    return 1;
}
```

FIGURE 8. This code displays "Insert USB disk" on the LCD screen and calls the pdfcrack program through system calls when a button connected to P9_12 is pressed.

I'll leave it up to the reader to find other places where additional information ought to be displayed to the LCD. However, make sure to include the following two lines on the header file (e.g., `pdgCrack.h`) of every file you would like to use with the libraries provided in `BeagleBone_io.tar.gz`:

```
#include "BeagleBone
    _gpio.h"
#include "BeagleBone
    _hd44780.h"
```

Finally, edit the included Makefile from the "PDF Crack - A Password Recovery Tool for PDF Files" and add these two libraries to the build process by ensuring the pdfcrack section is as follows:

```
pdfcrack:
    BeagleBone_gpio.o
    BeagleBone_hd44780.o
    main.o rc4.o \ md5.o
    pdfcrack.o pdfparser.o
    passwords.o common.o
    benchmark.o
    gcc $(CFLAGS) -o
    $@ $+
    strip $@
```

Now, we are ready to compile and run the modified pdfCrack and also the program that will launch the cracking application (code from **Figure 8**). This is done over the next three lines:

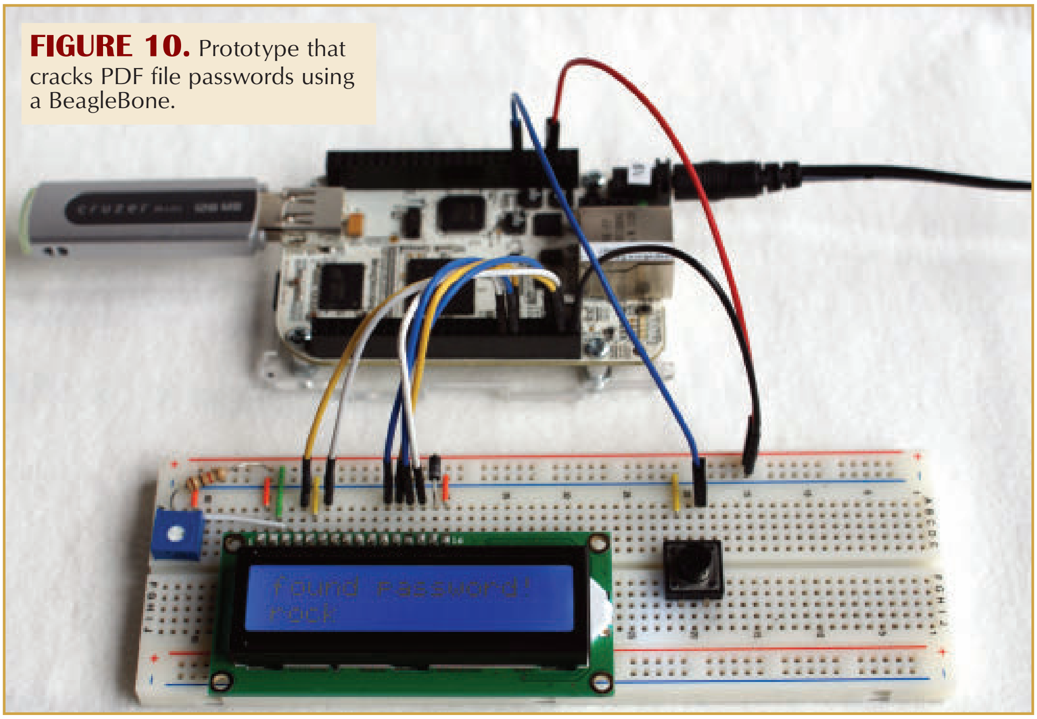
```
gcc BeagleBone_gpio.o
    BeagleBone_hd44780.o
    myCrack.c -o myCrack
make
./myCrack
```

In these commands, the first line will build the program entry point (myCrack), the second line will build the modified pdfCrack with LCD support, while the third line will start the cracking program. Attach a five volt power supply to the BeagleBone, disconnect the USB cable that links the BeagleBone to the computer, and you are ready to run the password cracking program without any external computer. **Figure 10** shows my final prototype, completely disconnected from a host computer and running off a 5V power supply. As shown in the image, the password for the encrypted file inside the USB disk is "rock."

```
/** Prints out the password found */
static void
foundPassword(void) {
  char str[33];
  int fin_search;
  size_t pad_start;

  memcpy(str,currPW,currPWLen);
  str[currPWLen] = '\0';
  printf("found %s-password: '%s'\n", workWithUser?"user":"owner", str);

  //[ENABLING LCD SCREEN]============================================
  int selectedPins[]={P8_14,P8_12,P8_11,P8_5,P8_4,P8_3};
  struct gpioID enabled_gpio[6];
  initialize_Screen(enabled_gpio,selectedPins);
  clear_Screen(enabled_gpio);
  stringToScreen("found password!",enabled_gpio);
  goto_ScreenLine(1,enabled_gpio);
  stringToScreen(str,enabled_gpio);
  terminate_Screen(enabled_gpio,selectedPins);
  //[ENABLING LCD SCREEN]============================================

  /**
   * Print out the user-password too if we know the ownerpassword.
   * It is placed in password_user and we need to find where the pad
   * starts before we can print it out (without ugly artifacts)
   **/

  if(!workWithUser) {
    fin_search=-1;
    pad_start=0;

    do {
      fin_search = memcmp(password_user+pad_start, pad, 32-pad_start);
      pad_start++;
    } while (pad_start < 32 && fin_search != 0);

    memcpy(str, password_user, pad_start);
    if(!fin_search)
      str[pad_start-1] = '\0';
    printf("found user-password: '%s'\n", str);

  }
}
```

FIGURE 9. Modifying the static void foundPassword(void) function inside pdfcrack.c, such that the final password is displayed on the LCD screen.

FIGURE 10. Prototype that cracks PDF file passwords using a BeagleBone.



With So Many Code Modifications, I Think I am Lost

So many code changes can be overwhelming, especially for new Linux and C language users. I included a file (**www.nunoalves.com/**

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up to 7 analog sensors
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source/final_pdfCrack.tar.gz) containing all the steps outlined in this article, as well as some additional cracking statistics such as the number of passwords that the BeagleBone is brute-forcing per second. After downloading the file to a directory inside your BeagleBone, type the following to build the entire project:

```
tar -xvf final_pdfCrack.
   tar.gz
make
./myCrack
```

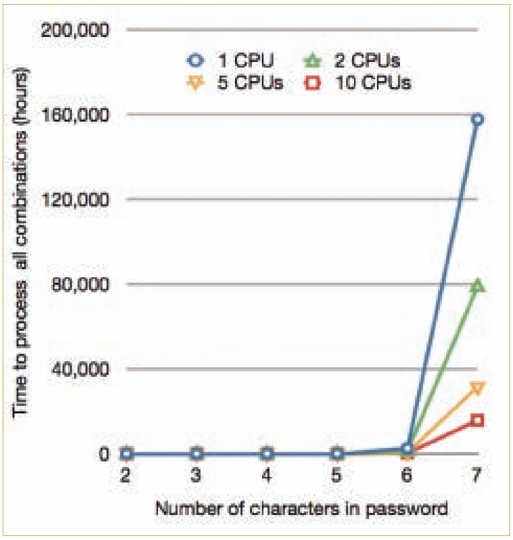

FIGURE 11. As we increase the number of CPUs, the theoretical number of passwords we can test per second dramatically increases, but it still takes an unreasonably long time to brute-force a seven character password.

Is This Practical?

In theory, this system looks promising but how long does it actually take to crack a password? From my experiments, the BeagleBone was able to brute-force test about 6,200 words per second. As a comparison, I also compiled the same exact code on my 2 GHz Core i7 Macbook Pro which could test (on average) 25,500 words per second. Both systems sound impressive, but how fast can they both crack a reasonably sized password?

A good password is generally long and contains at least one uppercase character, one lowercase character, and a digit. This means there are $(26+26+10)^n$ distinct words with **n** characters. If the BeagleBone is able to test 6,200 words per second, then it will take 39.7 minutes to test every single four letter word combination. Unfortunately, this system does not scale very well, as this brute-force method requires 41 hours to exhaustively test five letter words, and 106 days to process six letter words. Obviously, there is plenty of room for improvement here, such as a dictionary based option instead of brute-force, or even customized multi-core architectures with many BeagleBone CPUs.

This last option is the most interesting one. While the BeagleBone prototype system costs around $85, the CPU itself (TI AM3359) sells for around $5. With some clever engineering, we could potentially have a dedicated 10 core system for less than $300. However, for any password with more than seven characters — even if we have 10 CPUs all working in parallel — it would take 10 days to brute-force all six character words and 657 days for seven character words.

The graph in **Figure 11** clearly shows that using a multi-CPU BeagleBone as a brute-force password recovery system is far from being the ideal approach. In fact, brute-force password decryption methods are rarely the best method. However, if you are seriously interested in this method of password cracking, I recommend you delve into highly parallel computer architectures such as FPGAs and GPUs. Unfortunately, developing prototypes in these two architectures is far from trivial, but as the old saying goes, "anything easy is more trouble than its worth."

Regardless of the practicality of this implementation, this article is a good showcase of doing heavy duty computation on low power ARM devices, and another evidence that the BeagleBone can do pretty much everything a standard desktop computer can. **NV**

---

[1] - Julyan Ilett, "How to Use Intelligent LCDs," *Everyday Practical Electronics*, February 2007.

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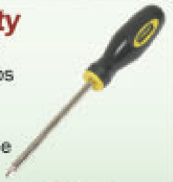

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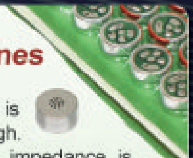

Primo electret microphone is 10mm diameter x 5.3mm high. Sensitivity -37.0dB ±3.0dB, impedance is 1.8kΩ, unidirectional, V_{CC} = 1.5V, and R_L = 2.0kΩ. Has 2 solder pads on back for hookup. Factory sealed box of 1000 microphones.

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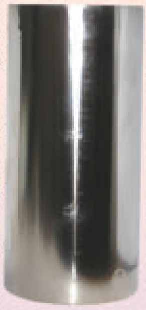

Large 7.75" x 12.38" x .005" thick sheet of Ultraperm 80 features a peel and stick surface on one side of the sheet. Ultraperm 80 sheet is a nickel-iron alloy (80.3% nickel, 14.3% iron, plus 4.6% molybdenum). It has very high magnetic permeability (400000 @ 0.73-0.5mm -50Hz maximal permability) which makes Ultraperm 80 very effective at screening static or low-frequency magnetic fields which are difficult to attenuate with other means. This shielding is commonly found around transformers in high end audio equipment, cathode ray tubes in oscilloscopes, etc.

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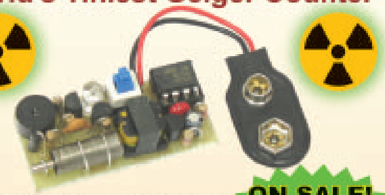

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Turn Your iPhone into a Plant Moisture Sensor

By Mike Westerfield

I was always a little jealous when Spock pulled out his tricorder on Star Trek and began measuring practically every physical value you could imagine. It's staggering how far technology has come, though. I carry a tricorder around in my pocket all the time now! Mine measures acceleration, rotation, and magnetic fields, giving both the strength and direction of each. It's not quite as sophisticated as Spock's, but it's also not so large and clunky. In this article, we'll look at a way to convert an iPhone or iPad into a quadcorder, hanging a HiJack AD converter off of the end, then using techBASIC™ to read it. As a sample project, we're going to build a moisture meter from off-the-shelf parts.

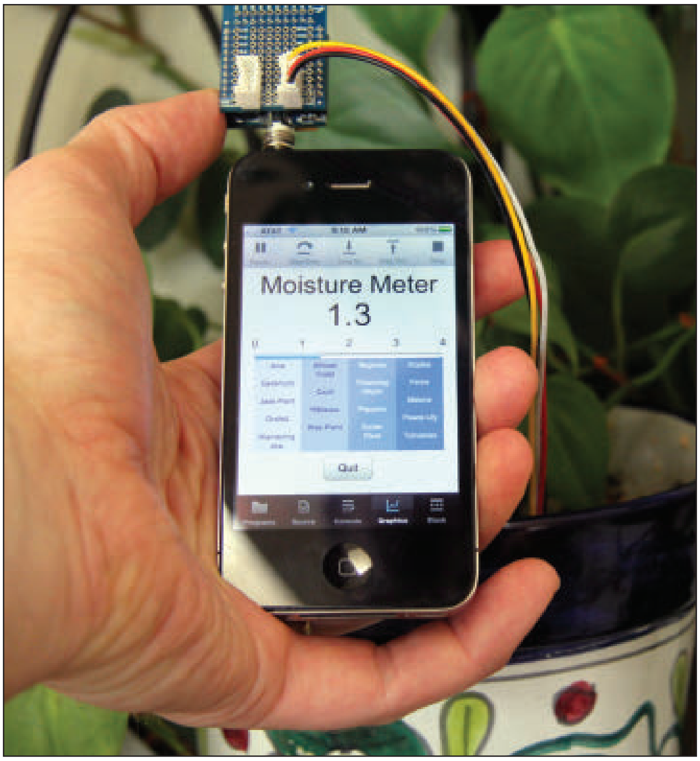


FIGURE 1. Our moisture sensor.

Most people who read a magazine like *Nuts & Volts* know a fair amount about electrical engineering, mechanical engineering, and programming, but few of us are really expert at all of them. That's what I find so enticing about the combination we'll work with here to build our moisture sensor. All of the components — even the software — are off-the-shelf. That lets us concentrate on the part of the project we're best at or — for those of us perverse enough to think this way — the part we're worst at, so we can improve. The whole project can be tossed together in a matter of minutes. Later, we'll deal with my area of expertise, and develop a much cooler implementation of the software so our quadcorder's moisture meter is easier to use.

Parts List

The first component is an iPhone or iPad. Depending on the model, this can give us an accelerometer, magnetometer, and gyroscope.

Next, we add the HiJack AD converter. This little device is just one inch square and 3/8 inches thick. It plugs into the headphone jack, drawing power from the audio output to provide 7.4 mW without the need of an external power supply. It reads a voltage drop, translating zero volts to a value of zero, and 2.75 volts to a value of

255, with a linear response between those values. A clever electrical engineer can connect pretty much any sensor to the iPhone using HiJack.

I bought the HiJack development kit which comes with the HiJack module, two prototype boards, a USB connector for updating firmware, and several wiring harnesses.

I used a Grove moisture sensor which attaches directly to the HiJack harness. Be sure and check out the other Grove components on the Seeed Studio site, though. You may be surprised at the number of components that are available, and most plug directly into HiJack.

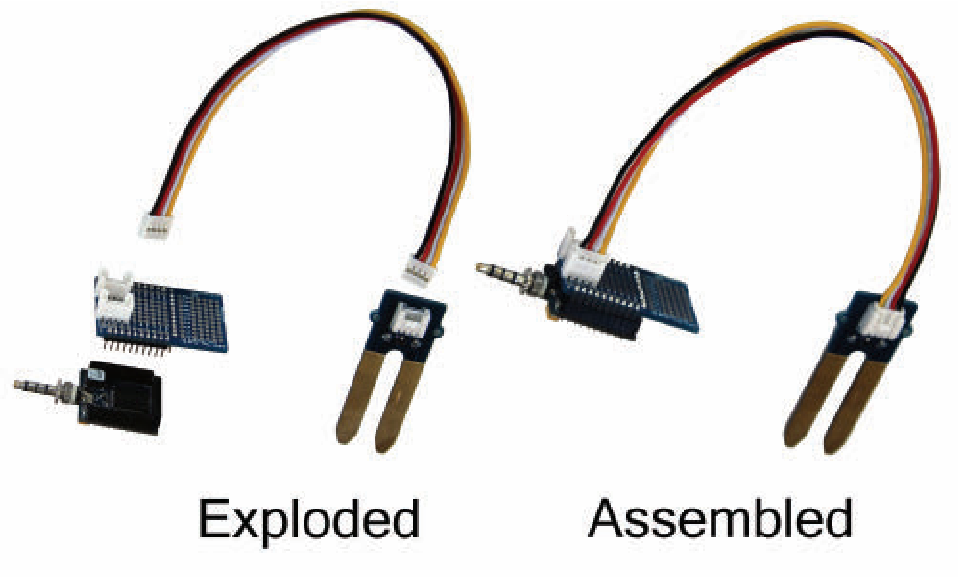


FIGURE 2: Exploded and assembled views of the hardware.

The last component is software to tie it all together. techBASIC is an implementation of Basic for the iPad and iPhone that is designed for collecting, analyzing, and displaying information. It comes with sample programs to read and display information from the accelerometer, gyroscope, and magnetometer, giving you your basic tricorder. The Byte Works' website (**www.byteworks.us**) has an introduction to HiJack; at the end is the source code for a program that will read the HiJack sensor and display the results more or less like an oscilloscope.

Assembling the Moisture Sensor

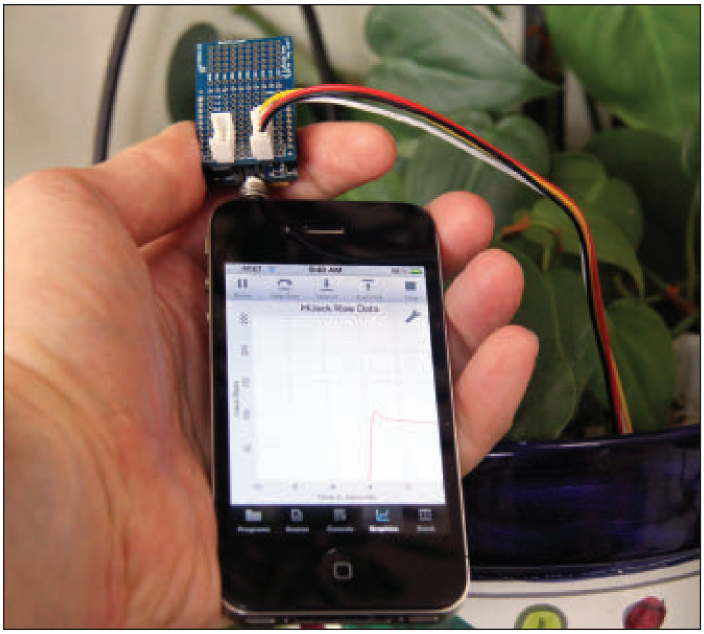
Figure 2 shows exploded and assembled views of the hardware. All of the parts except the moisture sensor come with the HiJack development kit. It really is as simple as it looks — just plug the components together as shown, then insert the headphone jack into an iPhone.

To use HiJack, you'll need to have some software installed. After downloading techBASIC from the app store, the next step is to install the HiJack software. Go to the HiJack blog on the Byte Works website, scroll to the bottom, and click the download button. You'll get a file called HiJack.bas. Follow these steps to move HiJack.bas to your iPhone or iPad:

1. Run iTunes and plug in your iPhone or iPad like you are going to sync it.
2. Select the iPhone or iPad from the list of devices in the left column.
3. Select Apps along the top button bar.
4. Scroll down until you see the File Sharing section.
5. Scroll down in the Apps section until you see techBASIC. Click on techBASIC.
6. Drag the HiJack.bas file to the techBASIC Documents section.

With everything connected, run techBASIC and tap on the HiJack program from the Programs list to run the HiJack app. Now run around the house, sticking the prongs of the moisture sensors in various plants, and you will see responses like the one in **Figure 3**.

FIGURE 3: HiJack software and hardware with the Grove moisture sensor.



Calibration

Calibration is an important part of creating any measurement instrument. To calibrate my moisture sensor, I compared it to a commercial plant moisture sensor which lists the moisture in a simplified range of one to four. Using potting soil and water, I compared the commercial moisture sensor and the HiJack moisture sensor. **Figure 4** shows the data. Linear regression using the program in **Listing 1** yields this conversion from HiJack readings to the moisture sensor readings:

```
m = -5.385531 + 0.07708447h
```

Better Software

While the general HiJack software works, it doesn't have much pizazz. We'll create a custom program to read the moisture sensor and present it in a much more pleasing way.

Let's look at the design for a moment before looking at how the program is written. The design serves as a roadmap for discussing the code.

The top of the screen is occupied by a large label reminding us what this program does. Below that is the digital moisture value in another label. We'll use a progress bar as an analog moisture meter; this is shown in **Figure 5** right below the five labels used to show the

Listing 1

```
! Perform linear regression on a CSV file. Each
! line of the file should contain an X and Y
! value separated by a comma.
!
! Determine the number of values.
name$ = "moisture.csv"
OPEN name$ FOR INPUT AS #1
n = 0
WHILE NOT EOF(1)
  INPUT #1, x, y
  n = n + 1
WEND
CLOSE #1

! Dimension an array for the values.
DIM v(n, 2)

! Read the values.
OPEN name$ FOR INPUT AS #1
FOR i = 1 TO n
   INPUT #1, v(i, 1), v(i, 2)
NEXT
CLOSE #1

! Find the sums of X, X^2, Y and XY. Also
! find the min and max X values for later
! use when drawing the fitted line.
sx = 0
sx2 = 0
sy = 0
sxy = 0
minX = 1E30
maxX = -1E30
FOR i = 1 TO n
  sx = sx + v(i, 1)
  sx2 = sx2 + v(i, 1)*v(i, 1)
  sy = sy + v(i, 2)
  sxy = sxy + v(i, 1)*v(i, 2)
  IF v(i, 1) < minX THEN minX = v(i, 1)
  IF v(i, 1) > maxX THEN maxX = v(i, 1)
NEXT

! Form the regression matrices.
A = [[sy,  sx],
      [sxy, sx2]]
B = [[n,  sy],
      [sx, sxy]]
C = [[n,  sx],
      [sx, sx2]]

! Calculate the slope and intercept.
c0 = DET(A)/DET(C)
c1 = DET(B)/DET(C)

! Create an array showing the fit.
DIM fit(0 TO 10, 2)
FOR i = 0 TO 10
  fit(i, 1) = minX + i*(maxX - minX)/10
  fit(i, 2) = c0 + c1*fit(i, 1)
NEXT

! Create the plot. Add the individual points
! and the fitted line.
DIM myPlot AS Plot, scatterPlot AS PlotPoint,
   fitPlot AS PlotPoint
myPlot = Graphics.newPlot
scatterPlot = myPlot.newPlot(v)
scatterPlot.setStyle(0)
scatterPlot.setPointStyle(2)
fitPlot = myPlot.newPlot(fit)
myPlot.setRect(0, 0, Graphics.width,
   Graphics.height - 41)

! Add a label showing the equation of the fit.
DIM equation AS Label
equation = Graphics.newLabel(0, Graphics.height
   - 31, Graphics.width)
equation.setAlignment(2)
e$ = "f(x) = " & STR(c0) & " + " & STR(c1) &
   "x"
equation.setText(e$)

! Show the graphics screen.
System.showGraphics
```

scale. There are four TextView objects below the progress bar. Color is used to show the relative moisture, starting with light blue for dry soil and moving to darker blue for wet soil. A few common plants are listed in each group; when the soil's moisture is at or below the level shown, it's time to water the plant. Finally, there is a Quit button at the bottom of the screen to stop the program.

The complete program is in **Listing 2**, which is available at the article link since it's too large to print. Instead, let's walk through it chunk by chunk.

```
! HiJack Moisture Meter

! Get the size of the graphics
! screen
width = Graphics.width
height = Graphics.height
```

We'll use the size of the graphics screen to calculate appropriate values for the position and size of controls. To save some typing, the program starts by placing these values in local variables.

```
! Paint the background light gray
bg = 0.9
Graphics.setColor(bg, bg, bg)
Graphics.fillRect(0, 0, width, height)
```

The default screen is white, and that just won't do. techBASIC has a built-in class called Graphics that is used to draw on the graphics screen. setColor and fillRect paint the entire screen a light gray.

```
! Create a Quit button
DIM quit AS Button
quit = Graphics.newButton(width/2 - 36,
   height - 57)
quit.setTitle("Quit")
quit.setBackgroundColor(1, 1, 1)
quit.setGradientColor(0.7, 0.7, 0.7)
```

Our program will be an event-driven program, so it will run until it is stopped. These lines create a Quit button centered near the bottom of the screen. Rather than the default white button, we're using a gradient to create a shadowed button.

To make the Quit button function, we'll need to add a subroutine that handles button clicks. Here's the one in our program, found near the bottom of the complete listing. It checks to make sure it was the Quit button that was tapped, then stops the program.

```
! Handle a tap on a button
!
! Parameters:
!   ctrl - The button tapped
!   time - When the button was
!      tapped
```

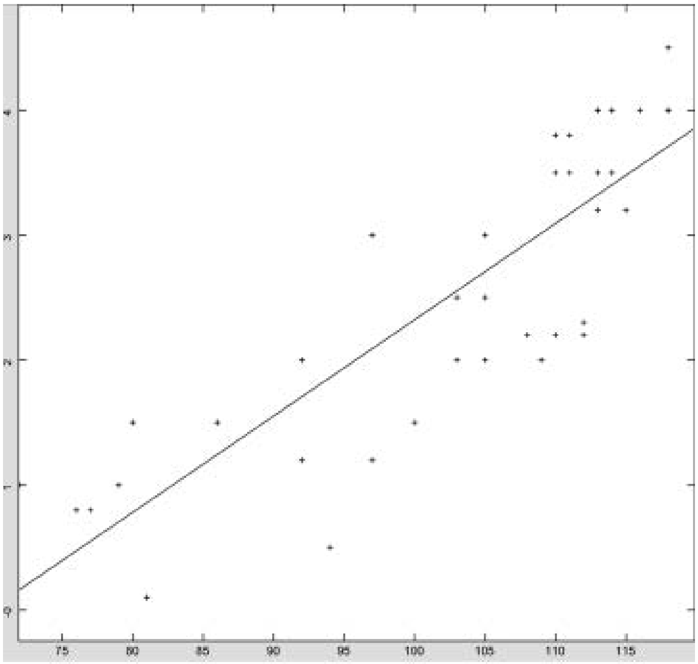
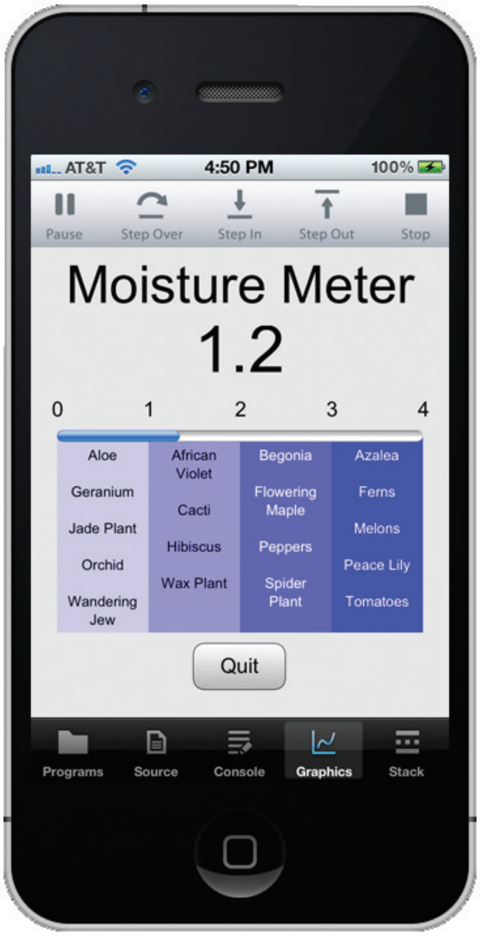


FIGURE 4: HiJack vs.a moisture sensor.



Moisture Meter

1.2

Aloe Geranium Jade Plant Orchid Wandering Jew	African Violet Cacti Hibiscus Wax Plant	Begonia Flowering Maple Peppers Spider Plant	Azalea Ferns Melons Peace Lily Tomatoes

FIGURE 5: Moisture sensor GUI.

```
SUB touchUpInside(ctrl AS Button, time AS
   DOUBLE)
IF ctrl = quit THEN
  STOP
END IF
END SUB
```

This is enough code to produce a working program. When you run it, you should see a Quit button on a gray background, and tapping the Quit button should exit the program.

```
! Put the name of the program at
! the top of the screen
DIM mmLabel AS Label
mmLabel = newLabel(0, 10, width, 40, 40,
   "Moisture Meter")
mmLabel.setBackgroundColor(bg, bg, bg)
```

This code creates a label. We'll be creating a lot of labels with various positions, sizes, and text, so this code is actually calling a subroutine in our program to do some of the repetitive work, followed by setting the background color for the label so it matches our screen background. Here's the subroutine that is called to create the label; it appears a bit later in the complete program listing.

```
! Create a label
!
! Parameters:
!   x - Horizontal location
!   y - Vertical location
!   width - Label width
!   height - Label height
!   fontSize - Point size for the
!      font
!   text$ - Label text
!
! Returns: The label

FUNCTION newLabel (x, y, width, height,
   fontSize, text$) AS Label
DIM nl AS Label
nl = Graphics.newLabel(x, y, width, height)
nl.setText(text$)
nl.setBackgroundColor(1, 1, 1, 0)
nl.setAlignment(2)
nl.setFont("Sans_Serif", fontSize, 0)
newLabel = nl
END FUNCTION
```

This subroutine creates a variable called nl — short for new label — to hold the label, then calls Graphics.newLabel to create the actual label. nl.setText sets the text for the label.

nl.setBackgroundColor sets the background color using the normal three red, green, and blue components which range from 0 to 1, but in this case, it also sets the alpha level. The alpha level controls how opaque the color is. By setting the background alpha level to 0, we're setting it to be completely transparent so anything under the label shows through. This means we don't have to set the background color for each label to the background screen color. Wait. Isn't that exactly what we did after creating the mmLabel a moment ago? Well, yes — but that was a special case. It turns out techBASIC puts a control on the graphics screen to give you some options for dealing with plots. We cover up this control by setting the background for the title label to an opaque color.

The next two lines center the text and set the font size. Finally, we set the return value and return the new label to the caller.

```
! Create a large label to show
! the moisture level
DIM value AS Label
value = newLabel(0, 60, width, 40, 50, "0")
```

The same newLabel subroutine is used here to create a large label that will display the digital readout for the moisture meter. We'll see the subroutine that actually sets the value later. For now, we start with a reading of 0.

```
! Add 5 small labels to show the
! moisture scale along the top of
! the moisture bar
DIM nums(5) AS Label
plantLabelWidth = (width - 40)/4
FOR i = 0 TO 4
  x = i*plantLabelWidth
  nums(i + 1) = newLabel(x, 115, 40, 20, 16,
     STR(i))
NEXT
```

Our newLabel subroutine is getting quite a workout! Here, we use it again to create five labels (0 to 4) that show the scale for the analog readout. The various calculations evenly space the five labels across an area of the screen that extends from 20 pixels from the left edge to 20 pixels from the right edge. This is the size we'll use in a moment for the progress bar we'll use as an analog meter.

```
! Create the strings that will
! name the plants in each
! moisture group
DIM plants(4) AS TextView, plants$(4)
addPlant("Aloe", plants$(1))
addPlant("Geranium", plants$(1))
addPlant("Jade Plant", plants$(1))
addPlant("Orchid", plants$(1))
addPlant("Wandering Jew", plants$(1))
addPlant("African Violet", plants$(2))
addPlant("Cacti", plants$(2))
addPlant("Hibiscus", plants$(2))
addPlant("Wax Plant", plants$(2))
addPlant("Begonia", plants$(3))
addPlant("Flowering Maple", plants$(3))
addPlant("Peppers", plants$(3))
addPlant("Spider Plant", plants$(3))
addPlant("Azalea", plants$(4))
addPlant("Ferns", plants$(4))
addPlant("Melons", plants$(4))
addPlant("Peace Lily", plants$(4))
addPlant("Tomatoes", plants$(4))
```

We're going to add four text views now; each of which will have a background color that indicates the relative moisture level and a list of common plants that should be watered when the soil is at or below the indicated level. The text views will slightly overlap the progress bar, so we want to create them first so the progress bar is drawn on top. This makes them look like an integral part of the analog meter, rather than an afterthought sitting below it. This first chunk of code sets up the text that will appear in each text view. It calls the addPlant subroutine that appears later in the listing.

```
! Add a plant name to a string
! containing plant names
!
! Parameters:
!   newPlant$ - New plant name
!   plant$ - Current plant names

SUB addPlant (newPlant$, BYREF plant$)
IF LEN(plant$) <> 0 THEN
  plant$ = plant$ & CHR(10) & CHR(10)
END IF
plant$ = plant$ & newPlant$
END SUB
```

This subroutine checks to see if the list of plants is empty. If not, it adds two new line characters to the string, then adds the new plant name.

```
! Add colored labels below the
! moisture bar showing the plants
! in each group
plantLabelHeight = 150
FOR i = 1 TO 4
  x = 20 + (i - 1)*plantLabelWidth
  color = 1 - i/5
  plants(i) = newTextView(x, 145,
      plantLabelWidth, plantLabelHeight, 11,
      color, plants$(i))
NEXT
```

Next, we create the four text views. There's a bit of algebra to make them fit evenly across the screen and to set the color, but most of the work is done in the newTextView subroutine. The color we're setting is actually the white level for the background of the text view, so it's brighter for the low moisture text views. We'll see how this is used as we work through the newTextView subroutine, again collected here from later in the complete program listing.

```
! Create a text view to show a
! list of plants
!
! Parameters:
!   x - Horizontal location
!   y - Vertical location
!   width - TextView width
!   height - TextView height
!   fontSize - Point size for the
!       font
!   color - White level for
!       background; the color will
!       be blue, lightened by this
!       amount
!   text$ - TextView text
!
! Returns: The text view

FUNCTION newTextView (x, y, width, height,
    fontSize, color, text$) AS TextView
DIM ntv AS TextView
ntv = Graphics.newTextView(x, y, width,
    height)
ntv.setText(text$)
ntv.setEditable(0)
ntv.setBackgroundColor(color, color, 1, 1)
IF color < 0.5 THEN
  ntv.setColor(1, 1, 1)
END IF
ntv.setAlignment(2)
ntv.setFont("Sans_Serif", fontSize, 0)
newTextView = ntv
END FUNCTION
```

Most of the newTextView subroutine should look familiar, since it's very similar to the newLabel subroutine we looked at earlier. Other than returning a text view instead of a label, there are really only two differences. The first is ntv.setEditable, which tells the control that the user can't edit the text. The other difference is the way the color is set. In this case, we set the red and green components of the background color to the value passed as the color parameter, then set the blue component to bright blue. If the color parameter has a high value — as it does for the control that appears to the left — the red and green components are fairly bright, too, giving a whitish-blue color. For controls towards the right where the moisture is higher, we dim the red and green color to make the control a deeper blue.

```
! Create the moisture bar
DIM moisture AS Progress
moisture = Graphics.newProgress(20, 140,
    width - 40)
```

The last control is the progress bar used as an analog moisture meter.

```
! Set HiJack to sample 10 times
! per second
HiJack.setRate(10)
```

The HiJack hardware has a variable sample rate. We can leave it at the default of about 42 Hz, but higher sampling rates use more power. Lowering it to 10 Hz saves power and — let's face it — even 10 samples per second is overkill for a moisture meter.

```
! Show the graphics screen
System.showGraphics
```

Finally, we tell techBASIC we want to see the graphics screen rather than the default, which is the text console screen. So far, we've done everything except actually read the HiJack sensor and display the results. We want to do that on a regular basis for as long as the program runs. The nullEvent subroutine is called repeatedly when the program is not doing something else, so it's the perfect place to read the HiJack device.

```
! Read and process HiJack values
!
! Parameters:
!    time - Event time

SUB nullEvent (time AS DOUBLE)
v = HiJack.receive
m = -5.385531 + 0.07708497*v(1)
IF m < 0 THEN m = 0
IF m > 4 THEN m = 4
moisture.setValue(m/4)
value.setText(STR(INT(m*10)/10))
END SUB
```

Each time this subroutine is called, it starts by calling HiJack.receive. This fetches a two-element array from the HiJack sensor. The first element is the 0-255 value returned by the AD converter, while the second is a time stamp indicating when the data is collected.

The next line converts the HiJack value to a moisture reading from 0-4, using the fit we got from calibrating the moisture sensor earlier. The following two lines pin the value to the desired range, discarding values that are above or below the supported range.

Finally, we set the analog moisture meter (dividing by 4 because progress bars expect a value between 0 and 1) and the digital readout (using the INT function to strip off all but one decimal point from the result).

Now, get out there and check your soil! **NV**

Resources

Here are some links to resources and locations where the parts can be purchased.

HiJack Development Kit
$79.00 US
www.seeedstudio.com

Grove Moisture Sensor
$4.99 US
www.seeedstudio.com

techBASIC
$14.99 US
www.byteworks.us/Byte_Works/techBASIC.html

Apple App Store
http://itunes.apple.com/us/app/techbasic/id470781862?ls=1&mt=8

HiJack Source Code for techBASIC
www.byteworks.us/Byte_Works/Blog/Entries/2011/12/7_HiJack_Hello_world!_Project.html

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Continued from page 9

A crystal filter for 30M would be 1,500 Hz higher or 10.140200 MHz. WSPR kits, as well as ready-to-go units, for 20M and 30M are available on eBay. Search for WSPR.

George Steber

Poor Man Problems

There appears to be an error in the calculations Ron used in his Poor Man's Seismograph article in the May '12 issue. He used the equation for the period of a simple pendulum; a weight suspended from a massless rod. His device is based on a uniform rod pendulum. The correct formula for the period of such a pendulum is 2 pi * sqrt(2 * length / 3g). As a result, the period of Ron's pendulum is approximately 0.816 seconds, not one second.

Phil Polstra

Thank you for your constructive criticism. Ahh, the joy of being a writer! You are right in your assessment that the pendulum described was not a simple pendulum. It started off as one using fishing line and a sinker; however, I could not get enough deflection of the piezo sensor. Therefore, I went to using a bar and didn't think about that I had changed it to a rod pendulum. You are correct in your calculations. Fortunately, the period of oscillation does not change the nature of the instrument to measure earthquakes. I also discovered there is

Continued on next page

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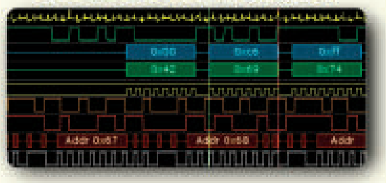
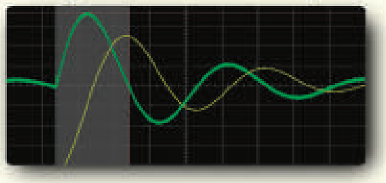
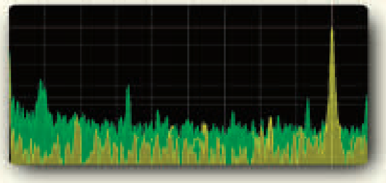

Digital Oscilloscope


Spectrum Analyzer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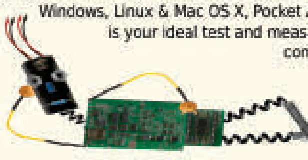
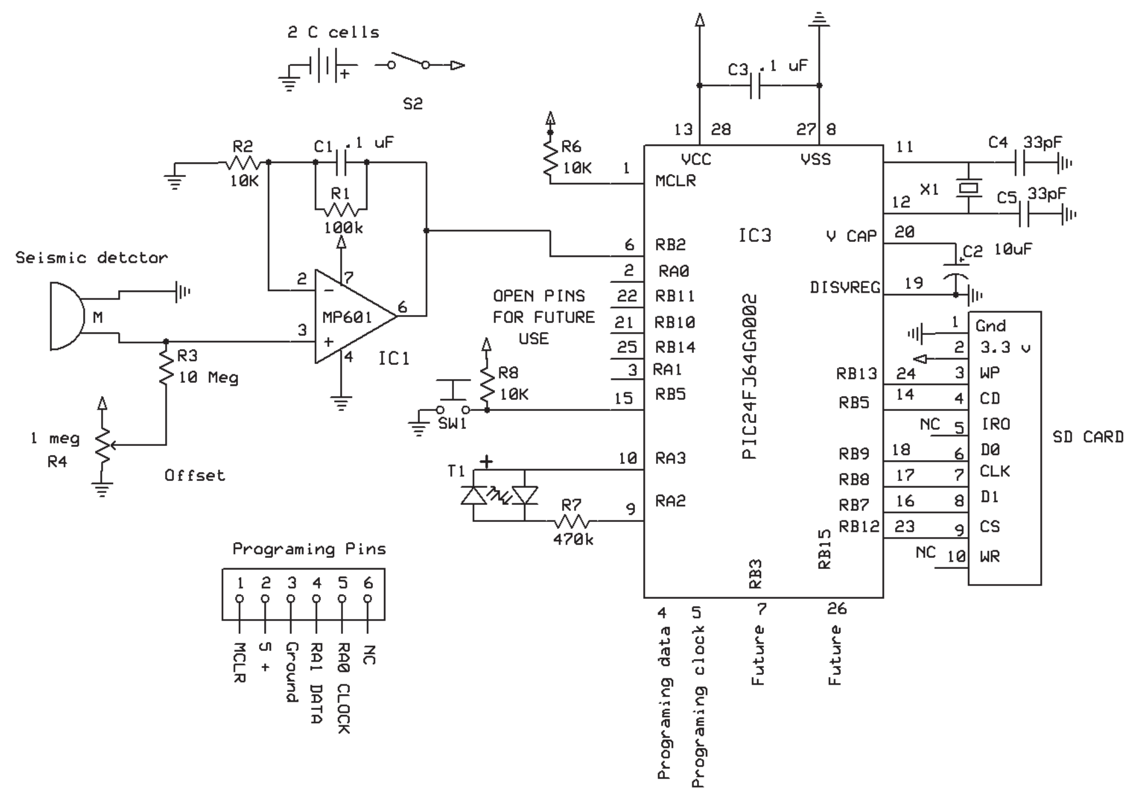

bitscope.com/nv

an error in the schematic. The seismic detector should go to ground and not pin 2 of the MP601. The corrected schematic is shown here. The Express PCB files on the N&V website are correct as are the boards sold by N&V.

Ron Newton



2 C cells
S2
R2
10K
C1 .1 uF
R1
100k
R6
10K
Seismic detctor
M
MP601
IC1
R3
10 Meg
1 meg
R4
Offset
OPEN PINS
FOR FUTURE
USE
R8
10K
SW1
T1
R7
470k
Programing Pins
1 2 3 4 5 6
MCLR
5 +
Ground
RA1 DATA
RA0 CLOCK
NC
C3 .1 uF
VCC
VSS
MCLR
IC3
PIC24FJ64GA002
RB2
RA0
RB11
RB10
RB14
RA1
RB5
RA3
RA2
V CAP
DISVREG
RB13
RB5
RB9
RB8
RB7
RB12
RB3
RB15
C4 33pF
X1
C5 33pF
C2 10uF
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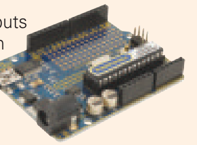

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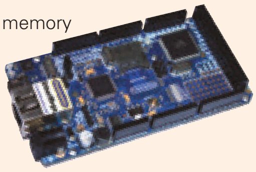

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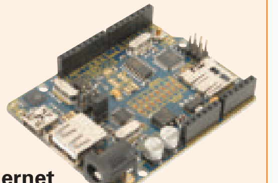

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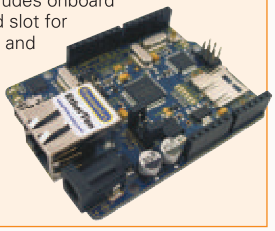
- Used as a web server, remote monitoring and control, home automation projects
- 14 digital I/O lines (6 with PWM support)
- 8 analog inputs



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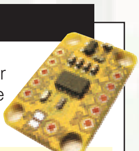

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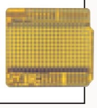

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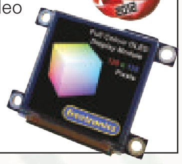

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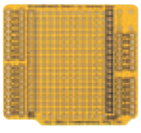

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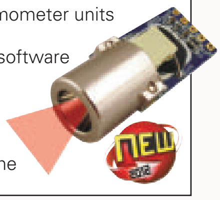

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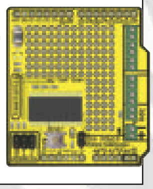

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#47

SMILEY'S WORKSHOP

C PROGRAMMING - HARDWARE - PROJECTS

by Joe Pardue

Persistence of Vision Wand

Follow along with this series! Joe's book & kits are available at www.nutsvolts.com

Discuss this article in the *Nuts & Volts* forums at http://forum.nutsvolts.com.

Recap

Last month, we finished up with C pointers (whew!) and we built a chaser light marquee frame using the Simple Chaser Lights kit available from *Nuts & Volts*. This month, we will study a C topic related to pointers: arrays. As a reward for our patience with the theory, we will build another project using the chaser lights kit: a POV (Persistence Of Vision) wand.

As before, this Workshop is split between some C theory and a tangentially related (but more fun) lab exercise that uses LEDs. We are nearing the end of the C theory, and soon will just use it and refer back to these articles when we show the C code. So, save your back issues! They might come in handy some day when you need a refresher on some arcane C concept.

■ FIGURE 1. Slinging the simple chaser lights board.

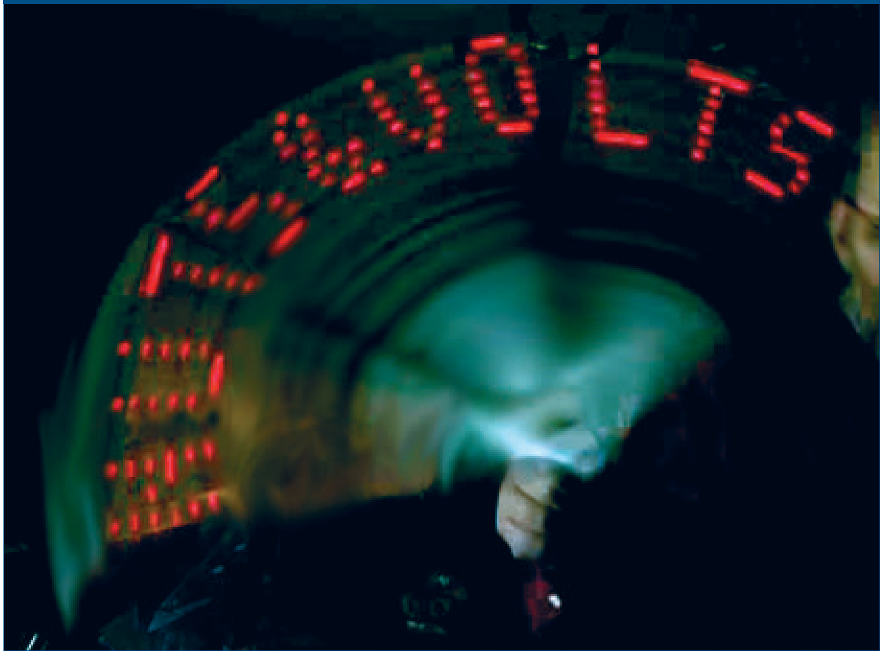


Figure 1 shows the chaser lights board tied down on a stick and swung madly about in a dark room where you can just see *NUTS & VOLTS* spelled out in the air. In the lab section this month, we will look at some of the principles behind the phenomenon of POV and will build the actual thing next month.

Theory: Arrays

Last month, you probably got good and sick of hearing about pointers. I hope that you also got how they work, because they are critical to serious use of the C programming language. After all that, we are now going to look at arrays that do many of the same things you'd do with pointers, but are a lot easier to understand. You might wonder why we didn't look at arrays first if they are easier. The reason is that you'd tend to skim over pointers if you learned arrays first. You'd think, 'Oh I can do that with arrays, no need to learn pointers!' Well, not exactly. Pointers and arrays are very closely related but not identical, and you will run into pointers a lot in C, so best learn them now rather than when your boss is standing over you with a whip.

Arrays

An array is a C data type that represents a sequence of memory locations. Think about that for a moment. Memory is where data is located and each of these locations has an address beginning at 0 and increasing all the way to the end of memory (okay, there are exceptions but they are not relevant here). When you create an array of size x, C will assign x contiguous locations in memory to that array. Say, for instance, you create 'char myArray[10]' — the C compilation process will find 10 contiguous locations in memory that are not in use. It will then assign the address of the first location to the 0 element of the array.

If the first memory location is the 12,718th byte in the AVR data memory, then the address of the first element (element 0) in myArray[0] is 12,717 and the address element 9 of myArray[9] is 12,727. Some folks get confused on counting since both memory and arrays start counting at 0 not 1. So, for a 10 member array the lowest location is 0 and the highest location is 9. Fortunately, you never have to know the address of myArray[0] since C uses the 'myArray[0]' as the alias for that address (you see myArray[0]; C sees 12717). It is also legal to just use the array name ("myArray") without the brackets as the address of (pointer to) the first element of the array. If we do the following:

```
myArray[4] = ‘1’;
```

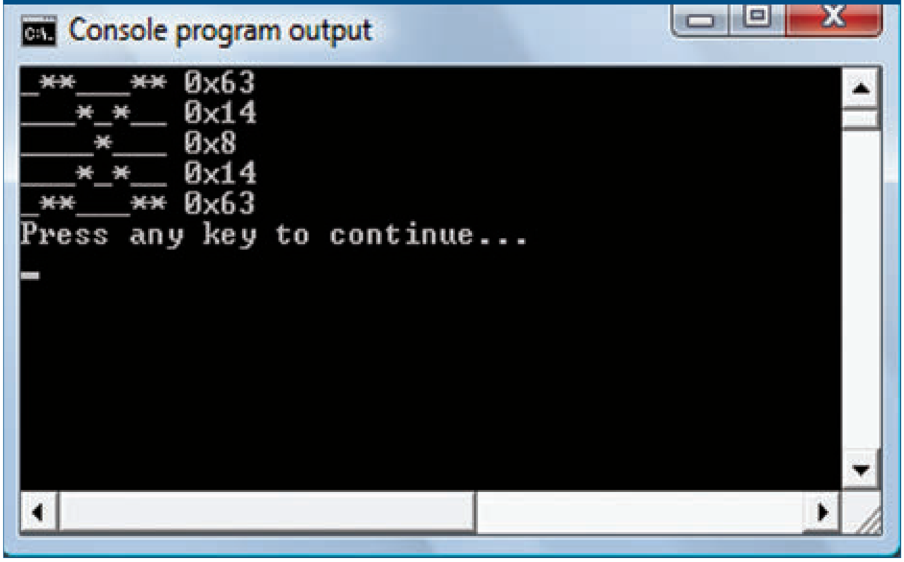
we are storing the ASCII code value for '1' which is the decimal number 49 at the memory location for myArray[4]. Remember that [4] refers to the fifth memory location since we start counting at 0, so that in our example 12,717 + 5 = 12,722. This means that when you write myArray[4], the C compiler generates the memory address 12,722. To repeat: myArray[4] is the data located at memory location 12,722 which is 'l' which is decimal 49. So, the operation shown above (myArray[4] = '1') stores an eight-bit byte with a value of 49 at the memory location 12722.

One of the most useful aspects of arrays is that the address of the first element of the array can be used as a parameter to a function to tell that function where the array is located. This gives you the ability to pass the full array of 10 values to a function by sending only the address of the first location in the array as a parameter. You can see the value of this since to pass the entire array as parameters means that 10 bytes would have to be pushed on the stack using valuable RAM. Using the address of the first byte, however, you only have to pass the address which — in our case — is an integer and two bytes long. Thus, we use two bytes for the address pointer versus 10 bytes for the data. If the array was 100 bytes long or a thousand bytes long, the address for the first element in the array would still be the same two-byte size.

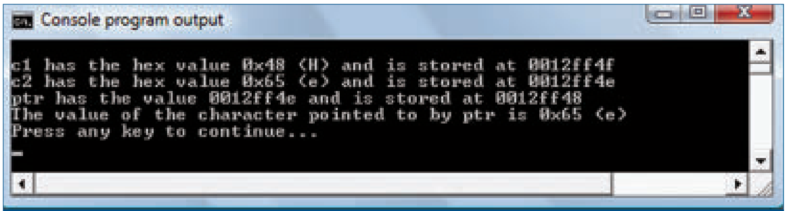
Let's look at a simple program to illustrate this. The following code is for an AVR, but now would be a good time for you to test your knowledge and port this to Pelles C like we used last month. You'd eliminate the usart.h include and calls to the usart. The code should then output the data shown to the Console Program Output rather than Bray's Terminal:

```
#include <stdio.h>
#include
“c:\avrtoolbox\libavr\source\driver\usart\
usart.h”

void load_array(char *);

// We do this so that it is easy for us
// to change the array size in one place
#define MAX_SIZE 10

int main()
{
  // Initialize usart for printf
  usart0_init_baud(57600);

  int i = 0;

  // Create an empty array
  char myArray[MAX_SIZE];

  // Initialize myArray to all 0
  for(i = 0; i < MAX_SIZE ; i++)
  {
    myArray[i] = 0;
  }

  // Show the data on the console before
  // loading it
  printf(“Before loading:\n”);
  for(i = 0; i < MAX_SIZE ; i++)
  {
    printf(“myArray[%d] = %d\n”,i,myArray[i]);
  }

  // Send it to a function to load it with data
  load_array(myArray);

  // Show the data on the console after
  // loading it
  printf(“After loading:”);
  for(i = 0; i < MAX_SIZE ; i++)
  {
    printf(“myArray[%d] = %d\n”,i,myArray[i]);
  }
}
```

■ FIGURE 2. X in console.



```
_**___** 0x63
___*_*__ 0x14
____*___ 0x8
___*_*__ 0x14
_**___** 0x63
Press any key to continue...
_
```



```
c1 has the hex value 0x48 (H) and is stored at 0012ff4f
c2 has the hex value 0x65 (e) and is stored at 0012ff4e
ptr has the value 0012ff4e and is stored at 0012ff48
The value of the character pointed to by ptr is 0x65 (e)
Press any key to continue...
```

■ FIGURE 3. Console pointer demo.

```
void load_array(char *thisArray)
{
   int i = 0;

   for(i=0;i<MAX_SIZE;i++)
   {
      // load it with ASCII codes for ‘0’ to ‘9’
      thisArray[i] = i + 48;
   }
}

Results in Bray’s Terminal:
Before loading:
myArray[0] = 0
myArray[1] = 0
myArray[2] = 0
myArray[3] = 0
myArray[4] = 0
myArray[5] = 0
myArray[6] = 0
myArray[7] = 0
myArray[8] = 0
myArray[9] = 0
After loading:myArray[0] = 48
myArray[1] = 49
myArray[2] = 50
myArray[3] = 51
myArray[4] = 52
myArray[5] = 53
myArray[6] = 54
myArray[7] = 55
myArray[8] = 56
myArray[9] = 57
```

Multi-dimensional Arrays as Function Parameters

You can have arrays of arrays, known as multi-dimensional arrays. For instance, you might have a two dimensional array where one dimension is the alphabet and the other is the graphic data to show a given character. So, for instance, alpha[3][5] might represent the third character ‘d’ and have five bytes associated with it to show it on a 5 x 7 LED matrix. In avrtoolbox, you’ll find font_5x7 which uses a two dimensional array to store the characters for the ASCII codes from 0x20 (space) to 0x73 (~). Since only 95 characters need to be used at 5 x 7 say, five bytes per ... that’s 475 bytes. Not a lot. That can be stored in program memory as shown:

```
Const char font[][5] PROGMEM = {
         {0x00,0x00,0x00,0x00,0x00},
             //    0x20 32
         {0x00,0x00,0x6f,0x00,0x00},
             // ! 0x21 33
         {0x00,0x07,0x00,0x07,0x00},
             // " 0x22 34

[a bunch of data left out to save space]

         {0x41,0x41,0x36,0x08,0x00},
             // } 0x7d 125
         {0x04,0x02,0x04,0x08,0x04},
             // ~ 0x7e 126
         };
```

[NOTE: PROGMEM was discussed in Smiley’s Workshop 25 in the Aug ‘10 *Nuts & Volts*.]

We use this data to map out the lighted LEDs that give a specific character. For example, the character ‘X’ is:

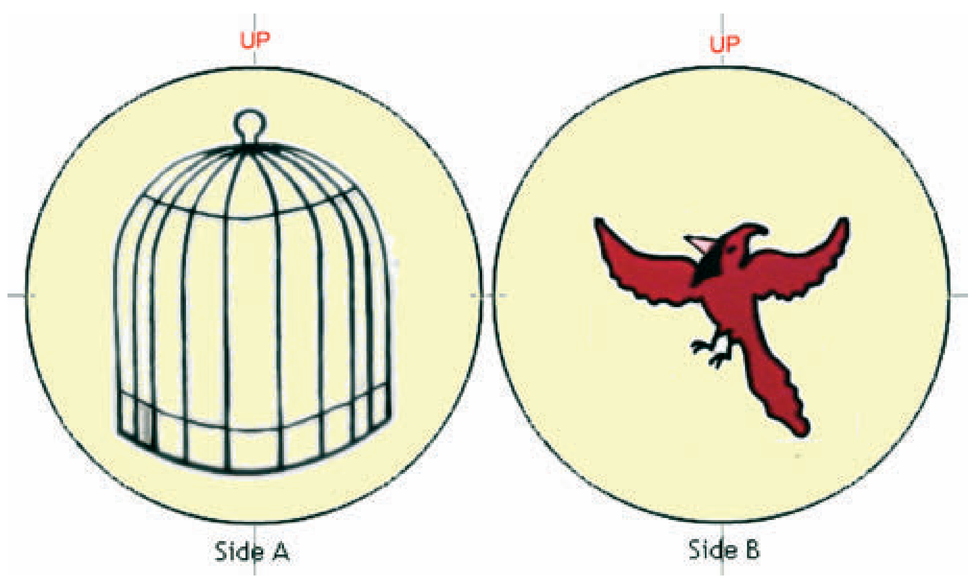
```
0x63,0x14,0x08,0x14,0x63},    // X 0x58 88
```

When we look at this in binary and character graphics, we see:

```
0x63  01100011  _**___**
0x14  00010100  ___*_*__
0x08  00001000  ____*___
0x14  00010100  ___*_*__
0x63  01100011  _**___**
```

■ FIGURE 4. Thaumatrope from the movie *Sleepy Hollow*.

The first set of brackets in the font array are left blank because we initialize the array with data, and C will count up the number of elements we are creating and then allocate memory for it. Beside each character in the array, you see the comment line. For instance, // ! 0x21 33 — this shows the character, the hexadecimal, and the decimal ASCII value for that character. Note that the first element in the font array is ASCII character number 32, and that the rest of the characters are sequential. This allows us to



■ FIGURE 5. Thaumatrope template.

address the character element by subtracting that ASCII value from the ASCII value for the first character in the array. Say what? The first character in the array is the space character ' ' with an ASCII value of 32. If we want to get the array element for the '}' character, then we can subtract ' ' from '}.' C knows that ' ' is 32 and that '}' is 125, so when you use the following: font['}' – ' '][0], C sees this as font[125-32][0] which is font[93][0], and that is equal to 0x41. From the font array, we see:

```
{0x41,0x41,0x36,0x08,0x00},
// } 0x7d 125
```

So:

```
font[93][0] == 0x41
font[93][1] == 0x41
font[93][2] == 0x36
font[93][3] == 0x08
font[93][4] == 0x41
```

If you want to test this with Pelles C, you can copy the font array from the font_5x7 file in avrtool box and append it to the following code, which will generate the pattern shown in **Figure 2**.

```
void print_binary(uint8_t num);
void print_5x7(uint8_t *font);

int main(int argc, char *argv[])
{
    print_5x7(&font['X'-' '][0]);
}

void print_5x7(uint8_t *font)
{
        for(int i = 0; i < 5; i++)
        {
                print_binary(font[i]);
        }
}

void print_binary(uint8_t num)
{
        uint8_t temp = 1;
        for(int i = 7; i >= 0; i–)
        {
                if(num&(temp<<i))printf("*");
                else printf("_");
        }
        printf(" 0x%x\n",num);
}
```

Lab

Well, I went way too long on the C theory this month, so I'll have to short-change things a bit in the lab. We'll just look at the POV concept and delay the details on how to convert the simple chaser lights board until next month.

Persistence of Vision

Persistence of vision is the retention of an image in the eye for about 1/25th of a second after the visual stimulus has been removed. POV accounts for us seeing movies as showing real motion when they actually only show still images at a rate of 24 frames per second. [Modern movies and televisions are a little more complex than this, but no need for the details here.]

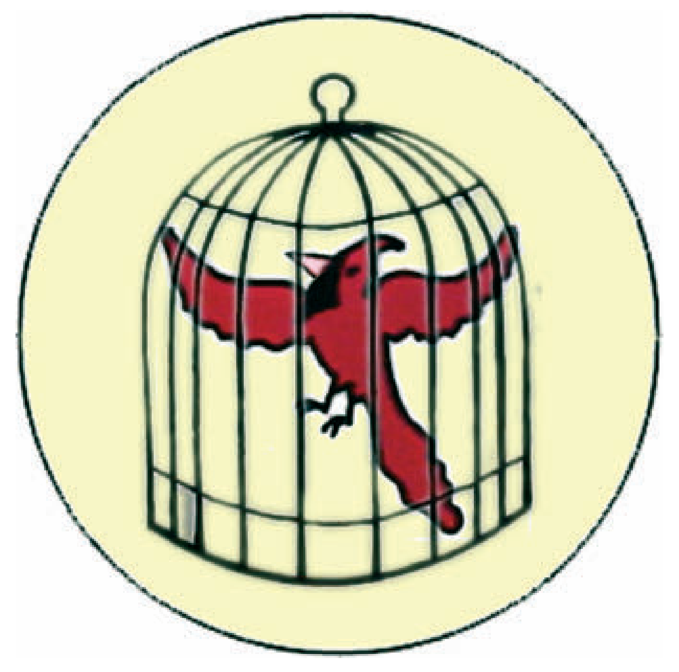
The Thaumatrope Magic Disk

The thaumatrope is a spinning disk toy that was popular in the 19th century. If you saw the movie *Sleepy Hollow*, you may remember the scene in **Figure 4** where Ichabod dreams about his mother showing him a cardinal in a cage using a thaumatrope. Ichabod shows Katrina the disk and they have the following dialog:

> KATRINA — *You can do magic! Teach me!*
> ICHABOD — *It is no magic. It is optics.*

Oh, what a stick in the mud! Of course it is magic. You can build your own by copying **Figure 5** and gluing it to a disk and attaching some string as shown in **Figure 4**. Just twirl away and impress three year olds everywhere.

NOTE: if you build the thaumatrope, be sure and have the bird and cage upside down relative to each other when you glue them front to back so that when the disc is spun, you will see the bird upright in the cage. This little project is kind of fun to do with kids, especially when you tell them about POV and how this was seen as a sort of magic long ago.



■ FIGURE 6. Thaumatrope spinning.

NUTS & VOLTS Out of Thin Air!

The simple chaser lights board (available from the *NV* webstore) shown in **Figure 7** has several POV messages programmed into it that can be selected using the leftmost five switch positions as follows:

Dipswitch Setting for POV Patterns:

10111xxx (23): pov_smiley_micros
11000xxx (24): pov_nutsvolts
11001xxx (25): pov_help
11010xxx (26): pov_stop
11011xxx (27): pov_ I_love_you
11100xxx (28): pov_ taxi
11101xxx (29): pov_right_arrows
11110xxx (30): pov_left_arrows

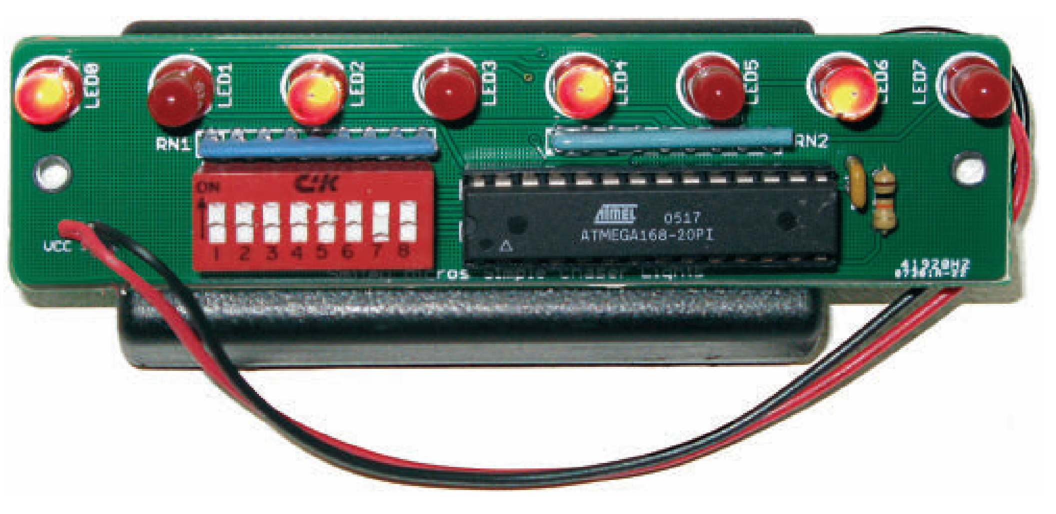
Theory is all well and good, but to really learn this stuff you have to get your hands on some tangible items that blink, whirr, and sometimes detonate. As a service for the readers of the Smiley's Workshop articles, we have simple and inexpensive projects kits available that can help you make it real. You can find these kits (and some darn good books) at the *Nuts & Volts* Webstore.

When I attacked the problem of making an LED POV wand, it attacked back. At first, I built one of those hand waving wands that you sweep back and forth to display a message, and I quickly found that this concept doesn't work as well as I thought. First off, if you are displaying the message to others, then you are standing behind the wand and have no way of knowing how the message looks other than to stand in front of a mirror. Doing so lets you get an idea about how fast you need to wave the wand and lets you change the waving so that the message starts at the beginning of a sweep and finishes at the end of the sweep. Having a mirror available is a bit of a stupid requirement. So, I decided that instead of all the hand waving, I'd just attach the chaser lights to a board with a handle on it and swing it in a circle. The results shown in **Figure 1** are with me slinging with my right hand and trying to take a picture with my left. (It took a lot of pictures to get one that had all the text in the frame.) The slinging technique requires less finesse in your timing, though you will want to practice in front of a mirror to get an idea of how fast to swing it.

Then, there is that problem that you might get the timing right, but the message will be showing at the bottom of the swing and appearing upside down. I built the device shown in **Figure 1** by cutting out a two foot length of Styrofoam, fastened the chaser lights board and battery box to it with a rubber band, and then jammed a pencil in one end for a handle to swing it with. No need to show it since it looks as bad as it sounds.

Okay, I get it now — the reason POV wands aren't more popular is that they require you to be in the dark, standing in

■ FIGURE 7. Simple chaser lights board.



Nuts & Volts now carries the entire line of Smiley Micros books and kits. Some are shown in the magazine and others in their web shop. If you just can't wait and want to get a leg up on real C programming for the AVR (while helping support your favorite magazine and technical writer), then buy my C Programming book and Butterfly projects kit, or if you are a complete novice try *The Arduino Workshop* and projects kit.

front of a mirror to make them work right. (Some lessons can only be learned by building something and after seeing it in action, realize that it was a stupid idea.) Yeah, sounded great on paper, but the reality is somewhat less than great. Technically, you could mount the chaser lights board on a motor and set the timing like one of those propeller clocks, and it would work just fine. You could also use an accelerometer and have software that senses direction change and speed. Who knows, I might decide one day that is a good project. So, let's declare that this whole POV wand was a great experiment and we learned a lot. Let's just move on to the next thing and hope not to embarrass ourselves again. **NV**

Questions? *Nuts & Volts* is hosting forums for its writers and you can find mine at **http://forum.servomagazine.com/**. If you want a really quick response — especially to a question not directly related to an article — you could put on your biohazard suit and start a thread on **www.avrfreaks.net**. Read my blog entry first that will tell you why you need the biohazard suit at **http://smileymicros.com/blog/2011/01/24/using-an-internet-forum/**.

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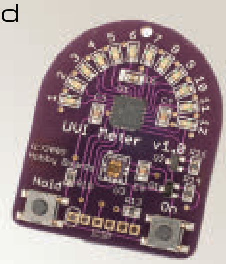

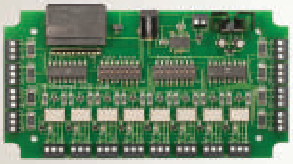

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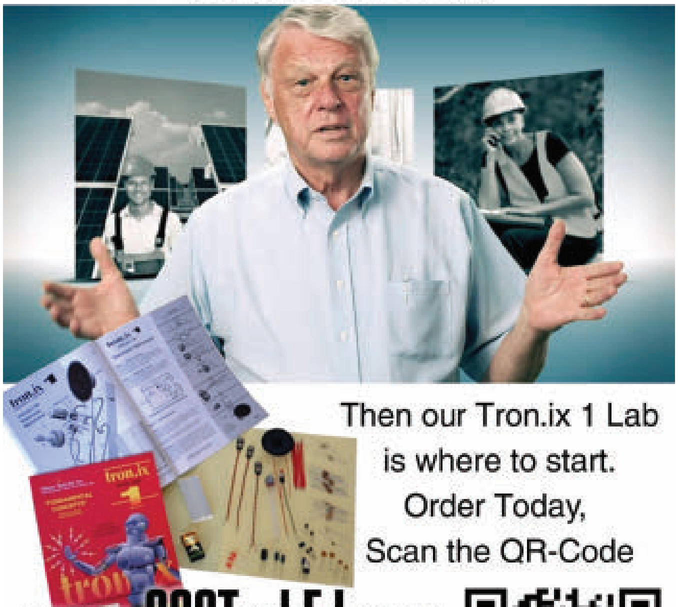

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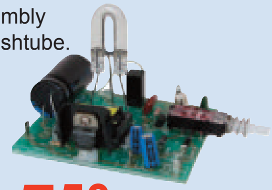

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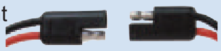

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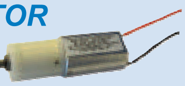

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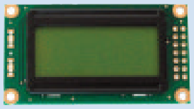

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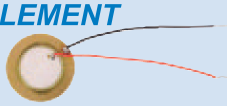

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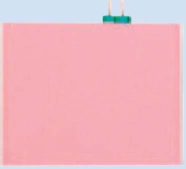

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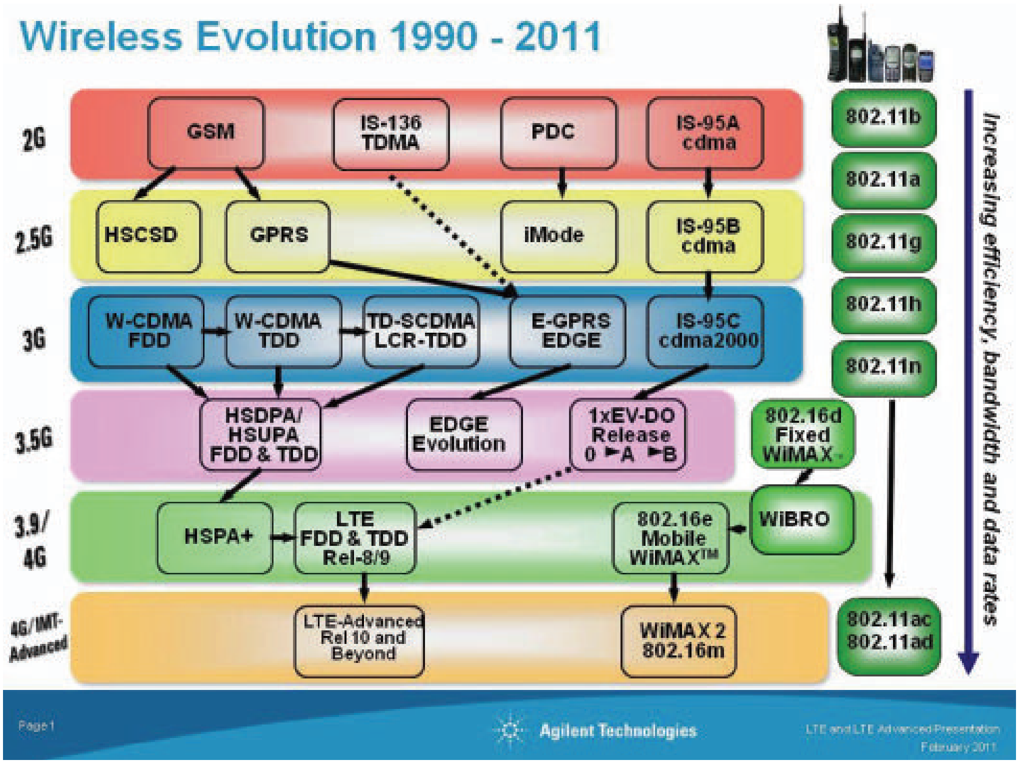
WHAT IS 4G WIRELESS?

3G/4G ... Does it really matter?

You probably have a cell phone, and chances are it is a smartphone. That means it uses either 3G or 4G technology. But what the devil does that really mean? And do you really care? Furthermore, does it really matter? We use lots of different technologies every day and don't really understand them. Nevertheless, those of you who are interested in communications technology may wish to have a better understanding of what those designations mean. Here is a crash course in cellular wireless.

THE GENERATIONS

The first generation cell phones that showed up in the late 1980s were simple phones using analog frequency modulation (FM). They were not much more than two-way radios or walkie-talkies. They worked well, and were so popular that the available radio spectrum was overwhelmed by too many subscribers. The cellular companies wanted the extra income from more subscribers, but were up against the spectrum shortage. Very quickly, a second generation (2G) cell phone system was invented. This 2G technology used digital voice and other digital methods to add more subscribers to the existing spectrum. **Figure 1** shows a snapshot view of the evolution of these generations.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LTE and LTE Advanced Presentation February 2011

■ FIGURE 1. A summary of the cell phone generations with the many standards and variations. Also shown on the right are the generations of Wi-Fi local area network standards. *Courtesy of Agilent Technologies.*

There were actually several 2G technologies developed. Three of them used time division multiple access (TDMA) to let three to eight more subscribers use a given channel. Another one designated IS-95A used what we call code division multiple access (CDMA) to put up to 64 subscribers into a larger 1.25 MHz channel. Only one of the TDMA systems (GSM) survived and is still used today. GSM is short for Global System for Mobile communications, which was developed in Europe and originally called Groupe Spécial Mobile. It puts eight users in a 270 kHz wide channel. CDMA assigns each user a special digital code which can be used to distinguish it from all other users sharing the same channel. Both are still used today worldwide. You still use one or the other for voice in your current phone.

During the second generation, the idea of transmitting data was implemented. Texting and email became possible by cell phone. These new technologies were often referred to as 2.5G. The GSM phones implemented something called General Packet Radio Service (GPRS), and later a faster version called Enhanced Data rates for GSM Evolution (EDGE). CDMA phones implemented 1xRTT (Radio Transmission Technology). Both were very slow but did get the data capability into phones with minimum expense.

The third generation (3G) phones came along in the late 1990s. Again, multiple standards were developed. The Third Generation Partnership Project (3GPP) and the International Telecommunications Union (ITU) created a wideband CDMA (WCDMA) system using 5 MHz channels called Universal Mobile Telecommunications System (UMTS). Qualcomm — the developers of CDMA — created cdma2000. Both offered data rates to 2 Mb/s, although that rate was rarely achieved in practice.

With texting and mobile email becoming a must and as more users demanded mobile Internet access, 3G became popular. The 3G technology was for data only, as voice was still by 2G methods. Various upgrades and new standards emerged forming 3.5G technologies making 3G data faster and more reliable. The WCDMA technology added high speed packet access (HSPA) and cdma2000 added Evolution-Data-Only (EV-DO).

Today, we are still basically in the 3G world. Most cellular systems are 3G. Most smartphones use 3G. The fourth generation (4G) is still in development, although there is some 4G deployment. The big question is, just what is 4G? It appears to have several definitions depending on who you talk to or what cellular carrier you use.

WHAT IS 4G?

The term 4G has multiple meanings. To the 3GPP and the ITU, it is not here yet and is still in a development stage. Others say that 4G is something called Long Term Evolution (LTE). LTE is indeed a 3GPP and ITU standard but they still call it 3G. Their definition of 4G is LTE Advanced — an even more improved version of LTE. Yet, the cellular carriers don't agree.

Some carriers generally mean that LTE is 4G, but not all. AT&T and Verizon call LTE 4G. Sprint implemented another technology called WiMAX that they call 4G. However, Sprint plans to change over to LTE in the near future. T-Mobile doesn't have LTE yet. In the meantime, they call their advanced HSPA network 4G. The general consensus is that LTE is the real 4G.

LTE was originally developed to be the follow-on to the GSM, UMTS, and HSPA technologies. However, those offering cdma2000 are also following the LTE path. LTE uses a completely different radio technology called orthogonal frequency division multiplexing (OFDM). It is a data-only technology designed for very high speed wireless access. What OFDM does is take a high speed serial data signal and divide it into many slower speed signals, then transmits them simultaneously over many different carriers in different channels. LTE takes its bandwidth (that can be 1.4, 3, 5, 10, or 20 MHz wide) and divides it up into many 15 kHz channels. Twelve of these carriers are bundled into 180 kHz wide resource blocks, forming a fundamental data unit. Each of the 15 kHz channels is then modulated with the subdivided data. Standard modulation types include QPSK, 16QAM, and 64QAM, depending on the desired data speed that can be achieved.

LTE also features something called MIMO for multiple input multiple output. MIMO uses multiple transmitters, receivers, and antennas to further boost the data rate and provide improved signal reliability. The high speed data is again divided up into multiple signals and each is sent to a separate transmitter and antenna. Then, the multiple signals are received by multiple antennas and receivers resulting in higher speeds. For example, a 2 x 2 MIMO system uses two transmitters and antennas, and two receive antennas and receivers. Various other configurations are possible, like 2 x 1, 4 x 2, and 4 x 4.

Using 64QAM modulation and 4 x 4 MIMO, a maximum downlink data speed of 100 Mb/s and maximum upload speed of 50 Mb/s is possible. Maximum configurations are not typical. Today, most MIMO systems are 2 x 1. It is not easy to put two receivers in each cell phone, however, it is possible to put two or four antennas at the cell tower. Generally today, the typical LTE cell phone can get 15 to 20 Mb/s or so downloads, which is generally faster than most home high speed Internet services.

Not all the cellular carriers have LTE yet. Verizon was the first and has the most LTE towers. They currently serve 38 cities. AT&T has LTE but has fewer towers, serving 31 cities. Both carriers are continually adding more LTE towers. Sprint will begin LTE later this year in a gradual transition from WiMAX. T-Mobile will eventually get LTE but in the meantime, have upgraded most of their systems to HSPA+ — a super 3G service that delivers speeds comparable to LTE (and even better in some cases). What T-Mobile's cute girl in the magenta dress is telling you is that they offer 4G "speeds."

While most people want the latest technology, they don't necessarily care what it is or how it works, just as long as the service and cell phone does what they want. Today, that includes not only texting and email, but also video, games, and fast Internet access. Most smartphones are still 3G and do a decent job of video and games. Plus, it's available in almost all US cities and worldwide. LTE is

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■ FIGURE 2. The Lumina 900 is Nokia's attempt to get into the smartphone market. It is a major contender thanks to the use of Microsoft's Windows Mobile 7.5 operating system with its unique tile touch user interface. It is an LTE 4G phone.

still in its rollout stage. That is expected to continue in the coming years as carriers find the capital to build more LTE cell sites.

One nagging problem for most carriers is the shortage of radio spectrum. They are using what they have and are trying to acquire more, but it is in short supply and very expensive. LTE uses very wide bandwidth channels, so it needs more spectrum than 3G. It will take time for the FCC to find more spectrum and auction it off to solve this problem.

WHAT TECHNOLOGY DO YOU HAVE?

The cellular technology you use depends on what carrier you use. If you have AT&T or T-Mobile service, you are using GSM, WCDMA, HSPA, and in the case of AT&T, LTE is available in some places.

If you get your service from Sprint, Verizon, or MetroPCS, you have the cdma2000 technology. Verizon has some LTE and Sprint has their WiMAX 4G service.

Incidentally, even if you do have HSPA, EV-DO, or LTE, the voice service is still 2G GSM or cdma. Ultimately, LTE is expected to carry voice but not soon, until the technology is worked out and the service is more widespread.

If you have a smartphone, you probably have 3G service. All Apple iPhones are 3G with most using HSPA+, including the latest 4S model. Apple has its own operating system called iOS. Other smartphones from Motorola, Samsung, HTC, LG, and others either have HSPA or some version of EV-DO. These phones use Google's Android operating system. Android smartphones predominate in

■ FIGURE 3. Apple's third iteration of its popular iPad has an improved display and is available with LTE 4G service from Verizon or AT&T.

numbers, with Apple iPhone next. Research in Motion (RIM) used to be the dominant smartphone vendor with their BlackBerry line but lost the lead to Apple and Android (although they are still a major vendor playing catch-up). They have their own OS.

One of the newest and most interesting smartphones is Nokia's Lumina 900 (**Figure 2**). Nokia is still the world leader in total cell phone volume, just not smartphones. They are trying to make a comeback with the help of Microsoft. Using the latest version of Microsoft's Windows Mobile operating system, they are offering a unique look. Instead of the usual icons on the screen, the Nokia smartphones with Mobile Windows divide the screen into many tiles, each representing one of the many things that the phone can do. The browser is Internet Explorer and the search engine is Bing.

The Lumina 900 is an LTE phone. It is available in the US from AT&T, but it may soon be available from others. Like all smartphones, it has two cameras: one eight megapixel, and the other one megapixel. The phone includes Wi-Fi 802.11n for connections to hot spots and other access points, and it has a Bluetooth connection for headsets. It also plays audio and video. The screen measures 4.3 inches diagonal using AMOLED touch technology. The resolution is 800 x 480 pixels. The Qualcomm processor runs at 1.4 GHz.

OTHER 4G PRODUCTS

If you need cellular coverage on your laptop, you can get a 3G or 4G USB dongle from most carriers. It is a blessing to have this when you just cannot find a hot spot to connect via Wi-Fi. LTE USB dongles are also now available. Another product getting LTE is Apple's latest iPad version (see **Figure 3**). All iPads include Wi-Fi but LTE is an option. No other tablets have LTE yet, but look for that to change in the near future.

BOTTOM LINE

Do you really need 4G? Most of us do not; 3G works perfectly well for most. Now you know how the technology works. Ultimately, 3G will be replaced by 4G LTE, but not for a while. That is why most phones are multimode, meaning that if you have LTE but there are no LTE towers nearby, you fall back to 3G with either HSPA or plain old WCDMA, or GSM for voice only. It's the same with other phones. If LTE is not available, you fall back to 3G cdma2000.

LTE Advanced will become available at some point with even faster data rates and other features, and the whole process will continue as the carriers have to upgrade their networks again. It will also take time for the handset vendors to come up with LTE-A phones. By the time that happens, the next standards will be in development so you can probably look forward to 5G phones within the next decade. **NV**

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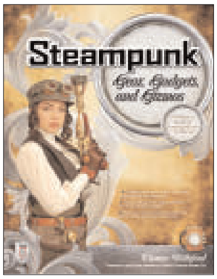

Welcome to the wondrous world of Thomas Willeford (a.k.a., Lord Archibald "Feathers" Featherstone) in which he shares his closely guarded secrets of Steampunkery. Filled with do-it-yourself projects, *Steampunk Gear, Gadgets, and Gizmos: A Maker's Guide to Creating Modern Artifacts* shows you how to build exquisite, ingenious contraptions on a budget.

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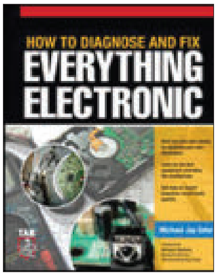

In this hands-on guide, a lifelong electronics repair guru shares his tested techniques and invaluable insights. *How to Diagnose and Fix Everything Electronic* shows you how to repair and extend the life of all kinds of solid-state devices, from modern digital gadgetry to cherished analog products of yesteryear. **About the Author:** Michael Jay Geier began operating a neighborhood electronics repair service at age eight that was profiled in *The Miami News*.

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Programming Arduino Getting Started with Sketches

by Simon Monk

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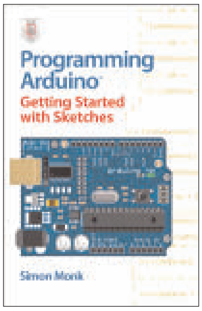

Using clear, easy-to-follow examples, *Programming Arduino: Getting Started with Sketches* reveals the software side of Arduino and explains how to write well-crafted sketches using the modified C language of Arduino. No prior programming experience is required! The downloadable sample programs featured in the book can be used as-is or modified to suit your purposes.

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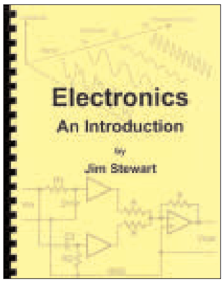

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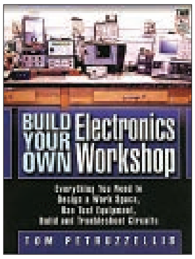

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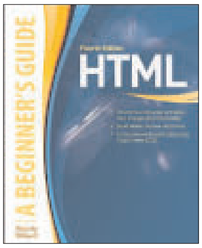

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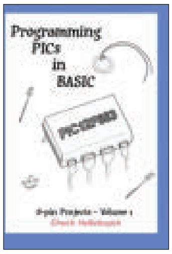

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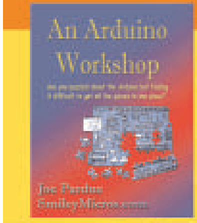

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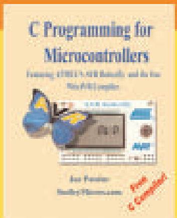

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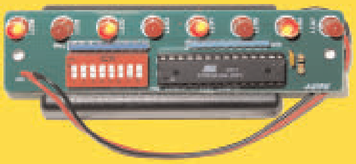

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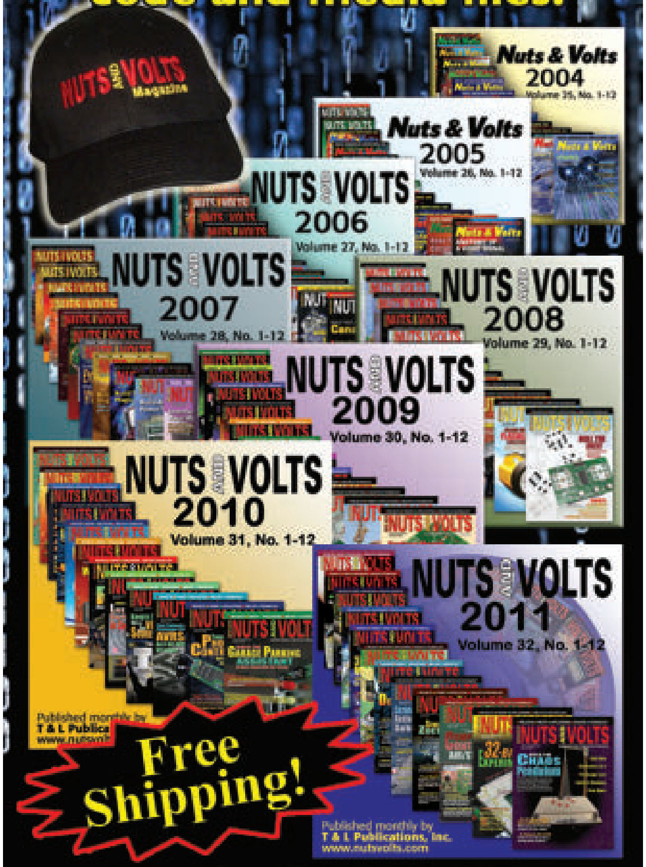

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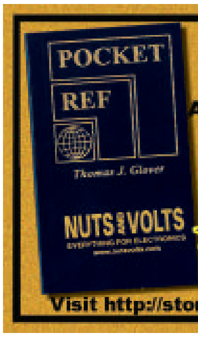

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PROJECTS

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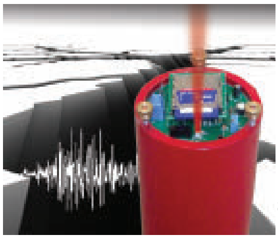
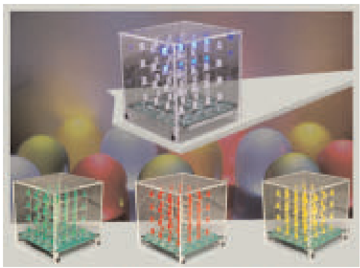


As seen in the May 2012 issue.
Now you can record your own shaking, rattling, and rolling.

The Poor Man's Seismograph is a great project /device to record any movement in an area where you normally shouldn't have any. The kit includes everything needed to build the seismograph. All you need is your PC, SD card, and to download the free software to view the seismic event graph.

Subscriber's Price **$79.95**
Non-Subscriber's Price **$84.95**

3D LED Cube Kit



This kit shows you how to build a really cool 3D cube with a 4 x 4 x 4 monochromatic LED matrix which has a total of 64 LEDs. The preprogrammed microcontroller that includes 29 patterns that will automatically play with a runtime of approximately 6-1/2 minutes.
Colors available: Green, Red, Yellow & Blue

Subscriber's Price **$57.95**
Non-Subscriber's Price **$59.95**

Battery Marvel Kit

MARVEL
BATTERY

As seen in the November 2011 issue.
Battery Marvel helps protect cars, trucks, motorcycles, boats, and any other 12V vehicles from sudden battery failure. This easy-to-build kit features a single LED that glows green, yellow, or red, indicating battery health at a glance. An extra-loud piezo driver alerts you to any problems.

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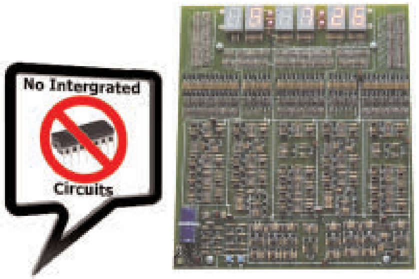
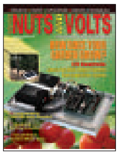
Transistor Clock Kit



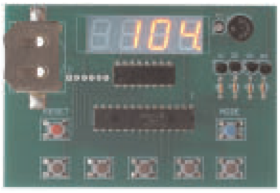
If you like electronic puzzles, then this kit is for you! There are no integrated circuits; all functionality is achieved using discrete transistor-diode logic. The PCB is 10"x11" and harbors more than 1,250 components! For more info, see the November 2009 issue.

Reg $225.95
Sale Price $199.95
PCBs can be bought separately.

Sorting Counter Kit



As seen in the July 2011 issue.



Sorting counters have many uses — keeping score, counting parts, counting people — it is just a handy gadget to have around. This is a very simple project for those who want to learn to solder or are interested in using microprocessors and how they function. No special tools are needed, just a small tip soldering iron. It has no box as it stands alone, therefore there is no drilling.

Subscriber's Price **$33.95**
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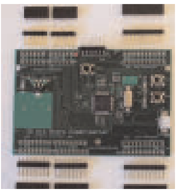
The 32-Bit Micro Experimenter is the fastest way to learn 32-bit microcontrollers.



The kit includes onboard 46 programmable I/O and USB, free software, carefully documented step-by-step experiments for USB, embedded web server, graphics and audio, wireless, RTOS, and file I/O. User pushbuttons, LEDs, and 32 kHz clock crystal. Can be used in solderless breadboard environment or stand-alone.

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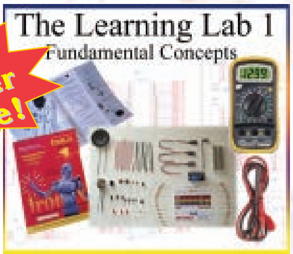

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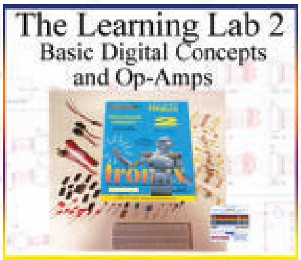

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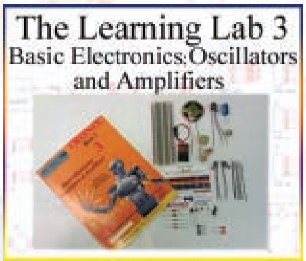

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The labs in this series — from GSS Tech Ed — show simple and interesting experiments and lessons, all done on a solderless circuit board.

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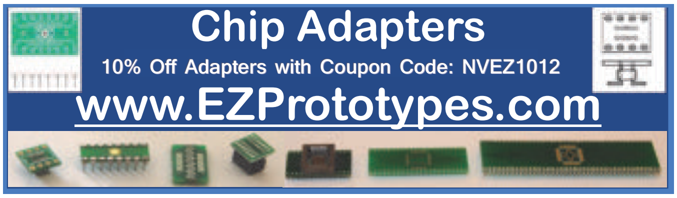
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■ BY FRED EADY

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SOME IEEE 802.15.4 TRANSCEIVER MAGIC

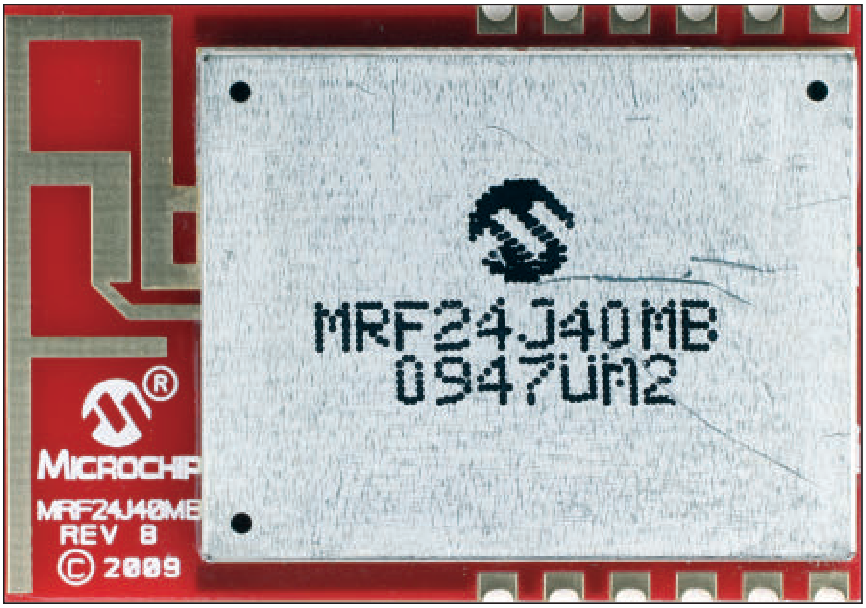
I love embedded Wi-Fi projects, but I'm beginning to really like doing USB projects. However, when it comes down to doing a lot with just a little, I'll take 802.15.4 over Wi-Fi and USB anytime. The typical 802.15.4 radio is a small low power unit that does its work in the multi-channel space of the 2.4 GHz ISM band. There are bunches of 802.15.4 radios out there. I happen to have (and like very much) the Microchip 802.15.4 radio set which includes MRF24J40MA and MRF24J40MB IEEE 802.15.4 2.4 GHz transceivers. I like these radios because thanks to the 802.15.4 code magicians and hardware gurus, we have a number of hardware and software tools available to us.

This month's Design Cycle is part build it and part code it with a heavy dose of "here's what it looks like" protocol sniffing. The discussion will revolve around the MRF24J40MB, which is the strong-arm version of the MRF24J40MA IEEE 802.15.4 2.4 GHz transceiver. We'll begin with a walk around the radios.

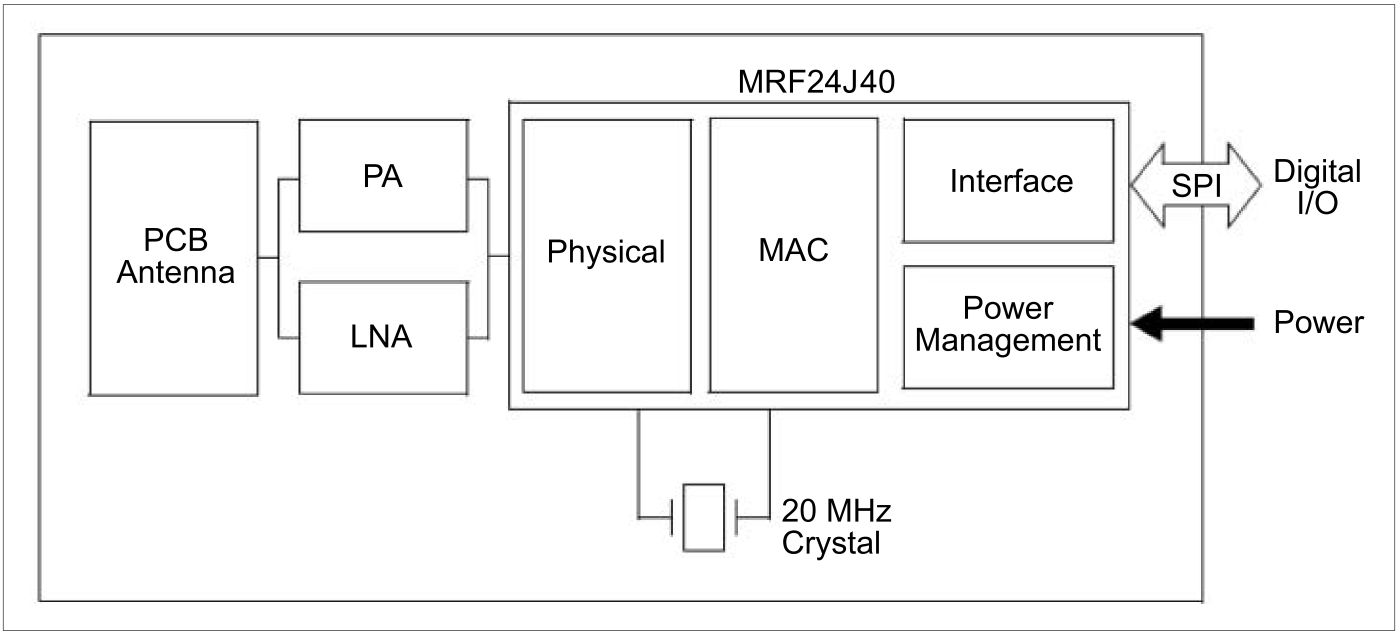
THE MRF24J40MB

The MRF24J40MA and MRF24J40MB operate identically in the eyes of the programmer and hardware designer. Both radios are based on the same RF IC: the Microchip MRF24J40. The MRF24J40MB IEEE 802.15.4 2.4 GHz transceiver you see in **Photo 1** differs from its little brother in the power output category. The MRF24J40MA pushes data into the Ether at 0 dBm, which equates to one milliwatt. The MRF24J40MB punches the Ether with a 100 milliwatt (+20 dBm) signal. The higher transmit power rating of the MRF24J40MB can propagate radio waves out to a maximum of 4,000 feet. And, you can drive the MRF24J40MB without a license. Unlike the MRF24J40MA, the MRF24J40MB has a bigger RF motor that is supercharged with a PA (Power Amplifier) and LNA (LowNoise Amplifier). The presence of the PA increases the MRF24J40MB's transmit power. Its receive sensitivity is enhanced with the addition of an LNA. Thus, the MRF24J40MB outperforms the MRF24J40MA on both the transmit and receive levels. The PA and LNA as they relate to the MRF24J40 are graphically depicted in **Figure 1**.

Although moving data is the ultimate goal, I'm more interested in capturing and



■ PHOTO 1. Most 802.15.4 radios are designed for reliable data transfer and distances no greater than a couple hundred feet. You can reach out and touch someone with the MRF24J40MB at distances of up to 4,000 feet.



■ FIGURE 1. The MRF24J40MB is simply an MRF24J40MA with a PA and LNA between the MRF24J40 802.15.4 IC and antenna.

analyzing the packets that carry the data. As for my kindred bit detectives out there, that's all well and good for us. However, on the other hand, it is important for all of us to understand how the MRF24J40MB interface is manipulated to allow transmission and reception of those bits within the data packets.

Keep your eye on **Figure 2** as we shuffle around the MRF24J40MB package. The MRF24J40MB active-low RESET pin is aptly named as it functions as a radio reset input. Any 802.15.4 radio worth its salt can hibernate like a fat bear in winter. The WAKE input drags a sleepy MRF24J40MB out of hibernation. The MRF24J40MB is a world class 802.15.4 radio module that can be put to sleep to conserve power.

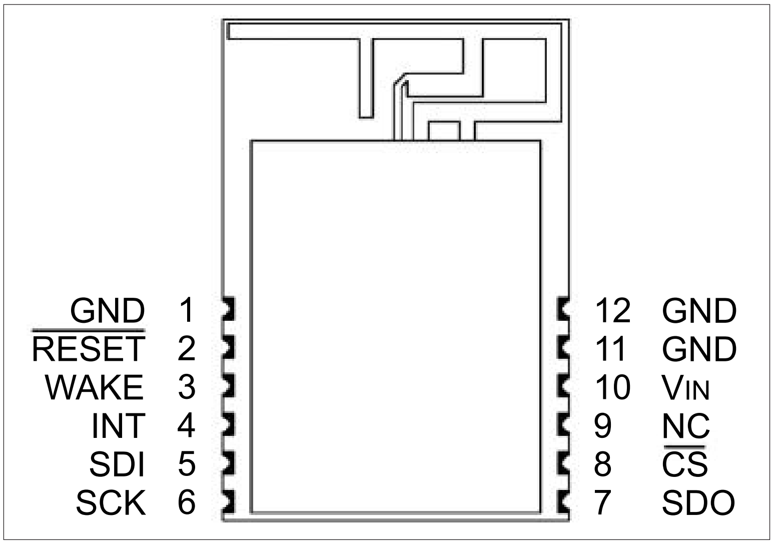
Today's typical microcontroller is fast enough to forego interrupts and poll external communications resources like the MRF24J40MB. However, those fast PICs are designed that way to allow them to get more work out of those quick CPU cycles. It is advantageous for a microcontroller to use its compute power as much as possible, and only be drawn off its main processing activity to service a device when required to do so. That's where the MRF24J40MB's INT (interrupt) output pin shines. The INT pin is an output that can be tied to one of the PIC's external interrupt inputs. When the MRF24J40MB needs to perform data I/O or do something the host microcontroller needs to know about, the MRF24J40MB activates its INT pin. The activation of the INT output forces the host microcontroller to run an interrupt handler routine to service the INT-initiated request.

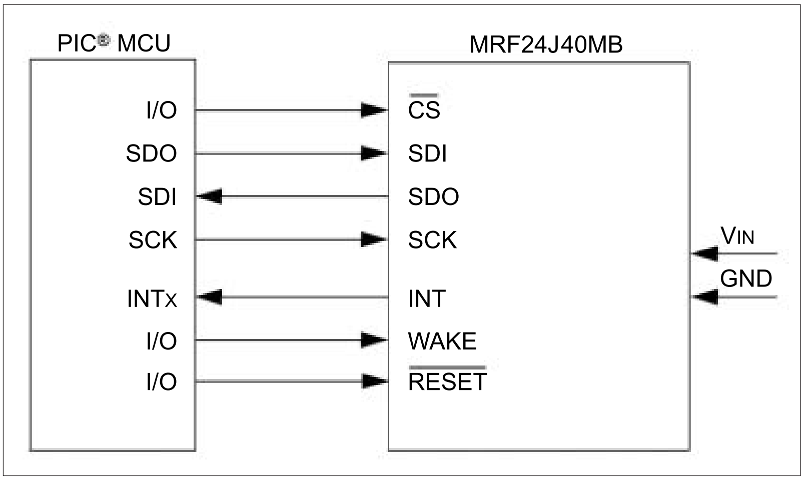
The MRF24J40MB's four-wire SPI portal is comprised of the SDO, SDI, SCK, and CS I/O pins. If you're old school, that's MOSI (Master Out Slave In), MISO (Master In Slave Out), Master Clock, and Chip Select, respectively. There is only one correct way to interface a Master SPI portal to the MRF24J40MB slave portal signals. If you build your application and hardware using one of the wireless protocol examples included in the MAL (Microchip Application Libraries), the SPI portal, INT, and I/O connections shown in **Figure 3** are already defined for you.

SOME BASIC 802.15.4 HARDWARE

It doesn't take much hardware to send and receive 802.15.4 packets. All we need is an SPI-enabled PIC and an MRF24J40MB. The bulk of the circuitry you see in **Schematic 1** is mounted on an EDTP Electronics,

■ FIGURE 2. The pinouts of the MRF24J40MA and MRF24J40MB are identical. The MRF24J40MB comes in a larger and wider package.



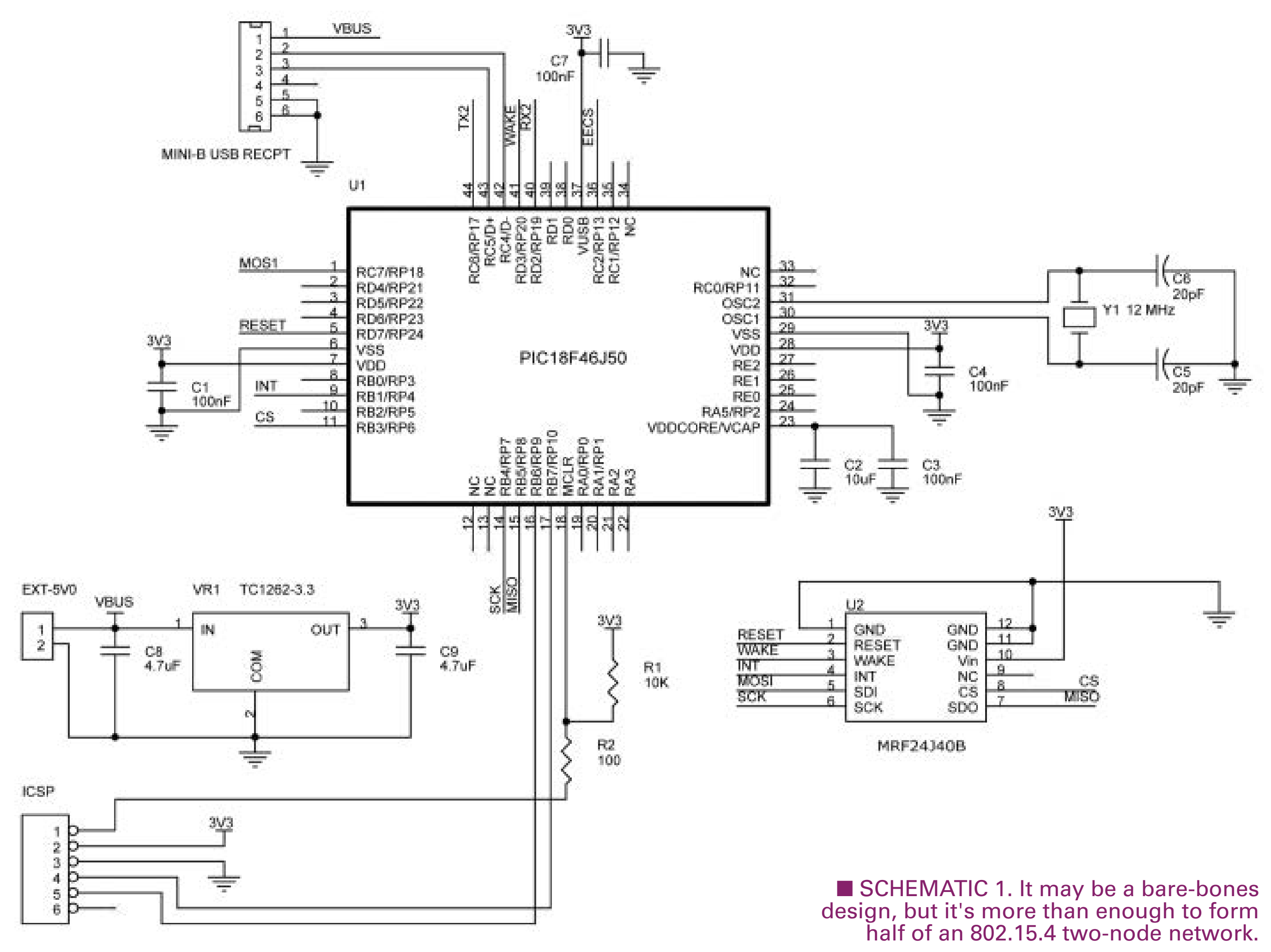

PIC® MCU
MRF24J40MB
I/O
SDO
SDI
SCK
INTx
I/O
I/O
CS
SDI
SDO
SCK
INT
WAKE
RESET
VIN
GND

■ FIGURE 3. This configuration works for every PIC. The pin numbers of the SPI portal, INT, and I/O pins are dependent on the particular microcontroller. Regardless of the pin locations, the SPI interface shown here operates identically on each PIC.

Inc., carrier board specifically designed for the PIC18F46Jxx/PIC18F47Jxx microcontroller families. Everything except the MRF24J40MB is mounted on this specially-designed printed circuit board (PCB) you see in **Photo 2**.

One of the best debugging tools is a serial port. So, I configured the PIC18F46J50 to supply a 19200 baud serial stream via I/O pin RC6. The associated serial receive pin is placed on I/O pin RD2. Normally, the serial port I/O pins are assigned to RC6 and RC7. Some of the PIC18F46J50's I/O pins that double as peripheral pins allow differing peripherals to be assigned to them. The Microchip term for this resource assignment process is Peripheral Pin Select (PPS). In this case, I assigned the PIC18F46J50's second EUSART to the RC6/RD2 I/O pin pair. Here's how I assigned the EUSART I/O pins:

```
EECON2 = 0x55;
EECON2 = 0xAA;
PPSCONbits.IOLOCK = 0;  //unlock PPS
RPINR16 = 19;           //RX2 to RP19
RPOR17 = 5;             //TX2 to RP17
EECON2 = 0x55;
EECON2 = 0xAA;
PPSCONbits.IOLOCK = 1;  //lock Peripheral
                        //Pin Select
```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C7
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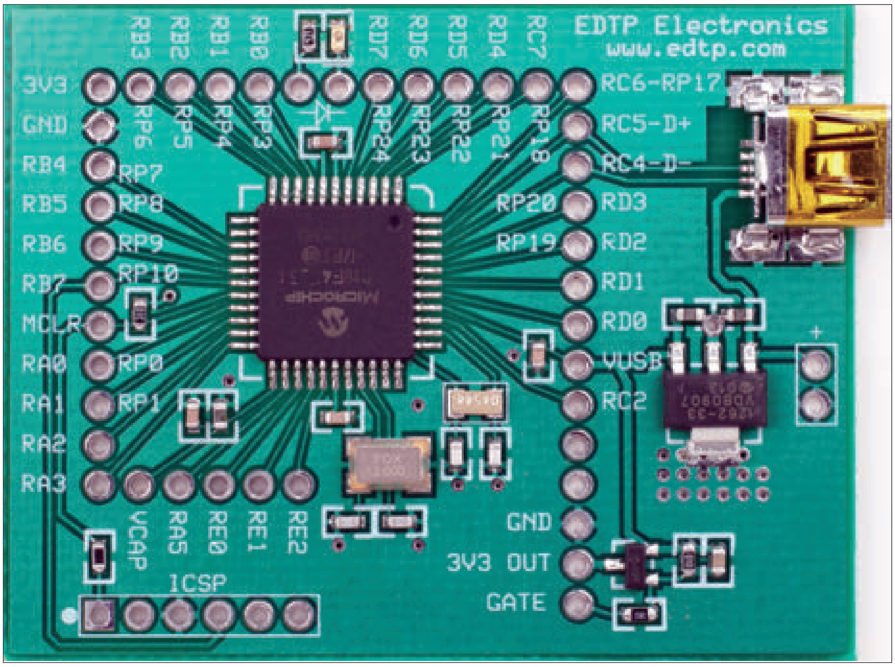
RX2
EECS
U1
MOSI
RESET
INT
CS
C1
100nF
PIC18F46J50
RC7/RP18
RD4/RP21
RD5/RP22
RD6/RP23
RD7/RP24
VSS
VDD
RB0/RP3
RB1/RP4
RB2/RP5
RB3/RP6
RC6/RP17
RC5/D+
RC4/D-
RD3/RP20
RD2/RP19
RD1
RD0
VUSB
RC2/RP13
RC1/RP12
NC
NC
RC0/RP11
OSC2
OSC1
VSS
VDD
RE2
RE1
RE0
RA5/RP2
VDDCORE/VCAP
NC
NC
RB4/RP7
RB5/RP8
RB6/RP9
RB7/RP10
MCLR
RA0/RP0
RA1/RP1
RA2
RA3
C6
20pF
Y1 12 MHz
C5
20pF
C4
100nF
C2
10uF
C3
100nF
SCK
MISO
EXT-5V0
VR1 TC1262-3.3
IN
OUT
COM
C8
4.7uF
C9
4.7uF
R1
10K
R2
100
ICSP
U2
GND
RESET
WAKE
INT
SDI
SCK
GND
GND
Vin
NC
CS
SDO
MRF24J40B

■ SCHEMATIC 1. It may be a bare-bones design, but it's more than enough to form half of an 802.15.4 two-node network.



■ PHOTO 2. This is one handy tool! Any 44-pin TQFP PIC with the same MCLR, power pin, and crystal layout can be mounted on this board.

All of the PPS peripheral functions can be found in the Peripheral Pin Select section of the PIC18F46J50 datasheet. Instead of lashing up a discrete RS-232 portal, I turned to Digilent. The Digilent PmodUSBUART can be seen in **Photo 3**. Using a six-pin inline Berg socket, I tied the PmodUSBUART's pin 2 to the PIC18F46J50's RP17 and the PmodUSBUART's pin 3 to RP19. The USB serial port was completed by tying the PmodUSBUART's GND pin to the GND pin on the PIC18F46J50 carrier PCB.

Now that we have a superior debugging port, the next step is to electrically install the MRF24J40MB. Check back with **Schematic 1** and you'll find that the SPI portal used by the MRF24J40MB is native to the PIC18F46J50. So, no PPS code is needed. However, we do need to invoke some PPS magic for the MRF24J40MB's INT pin. This won't take long:

```
    RPINR1 = 4;      // INT1 to RB1
```

The rest of the MRF24J40MB I/O pins that don't require PPS code are assigned and connected per **Schematic 1**. Let's not get too excited about the PIC18F46J50's USB capability just yet. We want to get the radio working first.

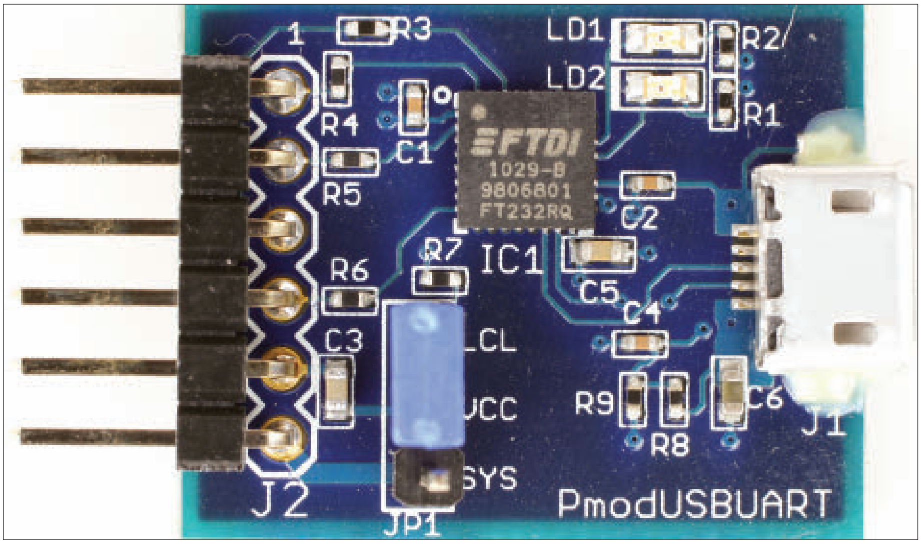
MICROCHIP 802.15.4 DEVELOPMENT TOOLS

If you've ever worked with Microchip's application libraries, you've probably done some configuration coding by way of a specialized include file. This is common practice in the various stacks that Microchip offers. It is a very efficient way to add and delete firmware features of the stack you're working with.

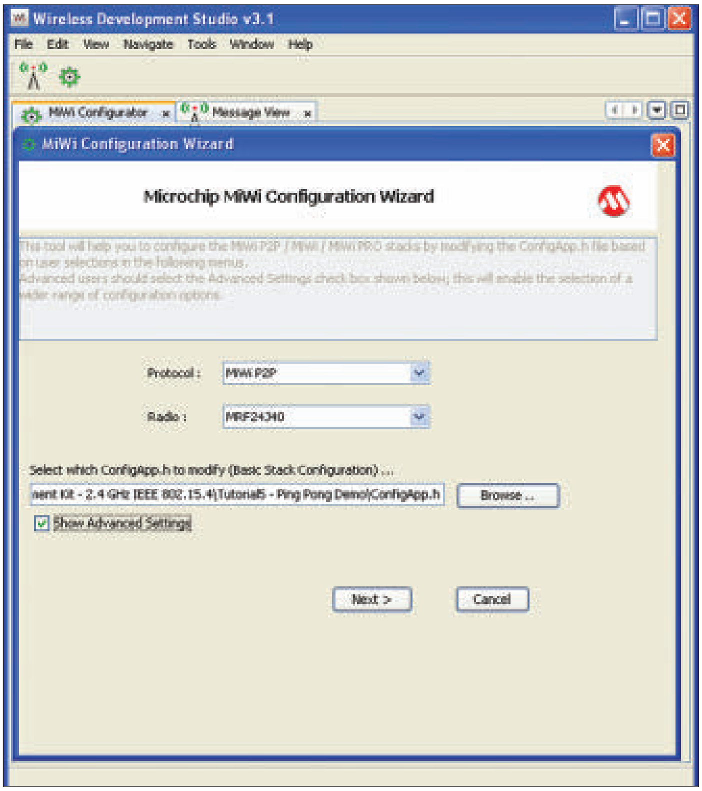
We are going to employ a variant of Microchip's proprietary MiWi stack which is based on the 802.15.4 protocol. Instead of a meshing network, we'll deploy a peer-to-peer — or P2P — network. Our starting point will be the configuration area of the Microchip Wireless Development Studio. The network configuration process begins in **Screenshot 1**. As you can see, we've elected to configure a MiWi P2P network using an MRF24J40-based radio. The radio setting will work with both the MRF24J40MA and MRF24J40MB.

Every check box you see in **Screenshot 2** represents a #define statement in the MiWi P2P ConfigApp.h file. Since we're configuring a P2P network, there are no coordinators. End devices are considered RFD (Reduced Function Devices) in a MiWi mesh network. There are no RFD devices in our P2P network topology.

Each P2P node must have a unique 64-bit identifier which is referred to as an EUI-64 (Extended Unique Identifier) node address. The EUI is the MAC — or hardware — address in the 802.15.4 world. The EUI-64 node address is built on an EUI-48. The most significant



■ PHOTO 3. This little Pmod has saved me tons of time. All you have to do to use it is hook up the TXD, RXD, and GND pins. The PmodUSBUART gets its power from the USB host portal.



Wireless Development Studio v3.1

MiWi Configuration Wizard

Microchip MiWi Configuration Wizard

This tool will help you to configure the MiWi P2P / MiWi / MiWi PRO stacks by modifying the ConfigApp.h file based on user selections in the following menus.
Advanced users should select the Advanced Settings check box shown below; this will enable the selection of a wider range of configuration options.

Protocol : MiWi P2P

Radio : MRF24J40

Select which ConfigApp.h to modify (Basic Stack Configuration) ...
nent Kit - 2.4 GHz IEEE 802.15.4\Tutorial5 - Ping Pong Demo\ConfigApp.h

☑ Show Advanced Settings

■ SCREENSHOT 1. Although you can manually edit the ConfigApp.h file, this interface is an easier alternative if you're new to the MiWi stack and 802.15.4.

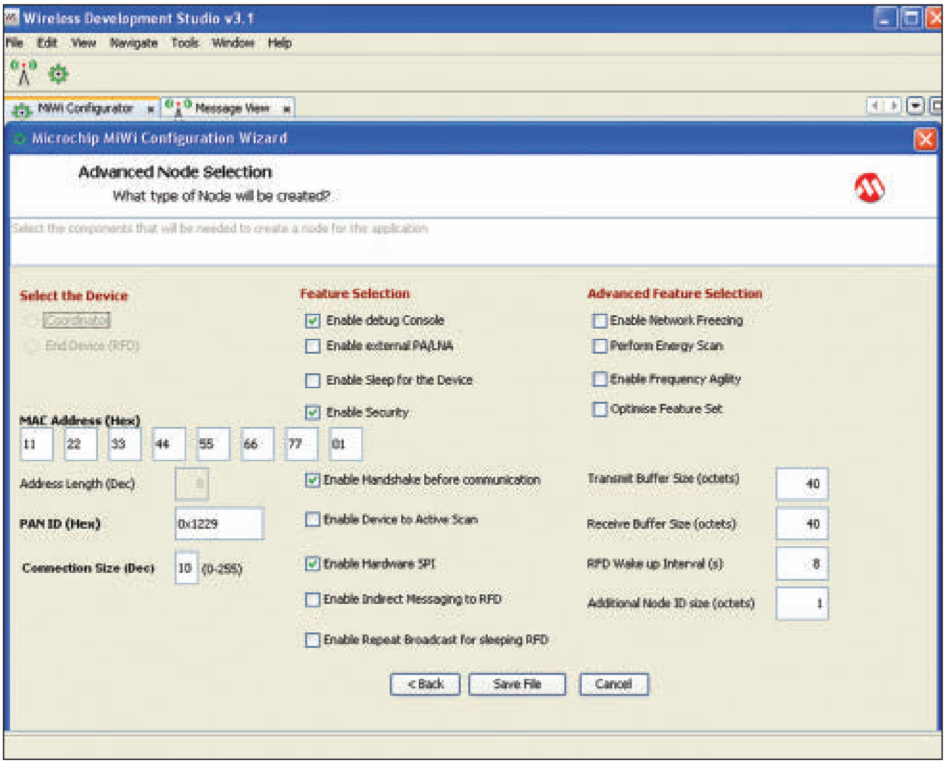
24 bits of an EUI-48 are actually a 24-bit OUI (Organizationally Unique Identifier). A 24-bit EI (Extended Identifier) is appended to the 24-bit OUI to form a EUI-48. The EUI-48 is the basis for the EUI-64. An EUI-64 is simply a 24-bit OUI followed by 0xFFFE (or 0xFFFF), followed by a 24-bit EI. The EUI is not a built-in part of the MRF24J40MA or MRF24J40MB. Like Ethernet, these MAC addresses must be purchased from the IEEE. Microchip has made the MAC address procurement process easier by offering an EEPROM that contains a non-volatile EUI-48 that can be converted to an EUI-64. The synthesis of an EUI is explained in **Figure 4**. The EUI-64 entered in **Screenshot 1** is totally bogus in the real 802.15.4 world, but it will work for our on-the-bench 802.15.4 P2P network. On the other hand, our PAN ID is perfectly valid.

In that we're communicating using MiWi P2P, many of the MiWi mesh features are not supported. Basically, we can secure our P2P packets and see any application-generated text via the MiWi stack's built-in console. The console will operate through the PmodUSBUART. This particular P2P node has 40-byte transmit and receive buffers, and can connect to a maximum of 10 nodes. The Enable Handshake before communication check box directly affects the ENABLE_HAND_SHAKE definition in the ConfigApp.h file. Checking this box allows this node to automatically pair with a peer node. Failing to turn on the ENABLE_HAND_SHAKE feature will limit the node to the use of broadcasting messaging only.

By adding one octet of additional node ID size, a programming space is reserved for anything we want to put into it. This extra octet means nothing to the MiWi stack, but it can be used by the application.

The power behind the check boxes is generated by MiApp and MiMAC. MiApp and MiMAC are APIs (Application Programming Interfaces). The idea behind MiApp and MiMAC is transparency. From an application standpoint, MiApp supports MiWi P2P and MiWi Mesh in the same manner. In addition to being a set of function calls, MiApp is a set of protocol configuration parameters defined in a configuration file. Using MiApp, the MiWi protocol can be altered with little change to the application code.

MiMAC is to radios what MiApp is to application code. MRF49XA and MRF24J40 transceivers can be interchanged with little or no effect on the application code. MiApp and MiMAC function calls are easily identified. MiApp_SetChannel (myChannel) is a MiApp function call, while MiMAC_SetChannel(BYTE



Wireless Development Studio v3.1

Microchip MiWi Configuration Wizard

Advanced Node Selection

What type of Node will be created?

Select the components that will be needed to create a node for the application

Select the Device

○ Coordinator
○ End Device (RFD)

MAC Address (Hex): 11 22 33 44 55 66 77 01

Address Length (Dec): 8

PAN ID (Hex): 0x1229

Connection Size (Dec): 10 (0-255)

Feature Selection

☑ Enable debug Console
☐ Enable external PA/LNA
☐ Enable Sleep for the Device
☑ Enable Security
☑ Enable Handshake before communication
☐ Enable Device to Active Scan
☑ Enable Hardware SPI
☐ Enable Indirect Messaging to RFD
☐ Enable Repeat Broadcast for sleeping RFD

Advanced Feature Selection

☐ Enable Network Freezing
☐ Perform Energy Scan
☐ Enable Frequency Agility
☐ Optimise Feature Set

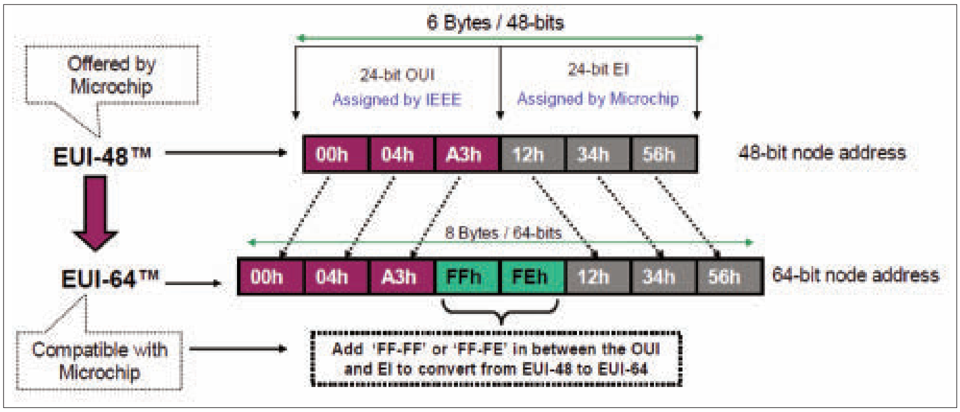
Transmit Buffer Size (octets): 40

Receive Buffer Size (octets): 40

RFD Wake up Interval (s): 8

Additional Node ID size (octets): 1

■ SCREENSHOT 2. Pretty slick, huh? We eliminate a bunch of finger work by using the check boxes in this view to do our P2P network configuration work.


6 Bytes / 48-bits
Offered by Microchip
24-bit OUI
Assigned by IEEE
24-bit EI
Assigned by Microchip
EUI-48™
00h 04h A3h 12h 34h 56h
48-bit node address
8 Bytes / 64-bits
EUI-64™
00h 04h A3h FFh FEh 12h 34h 56h
64-bit node address
Compatible with Microchip
Add 'FF-FF' or 'FF-FE' in between the OUI and EI to convert from EUI-48 to EUI-64

■ FIGURE 4. This is amazing! Networking stuff that really makes sense.

channel, BYTE offsetFreq) is obviously a MiMAC function call. All three Microchip radios are configurable using their Wireless Development Studio. Download and run your copy of it and you'll see that available features are dependent on the radio type and protocol you choose. That's MiApp and MiMAC in action. **Figure 5** depicts how MiApp and MiMAC interact with the application code and the configuration files.

THE NEW MICROCHIP ZENA

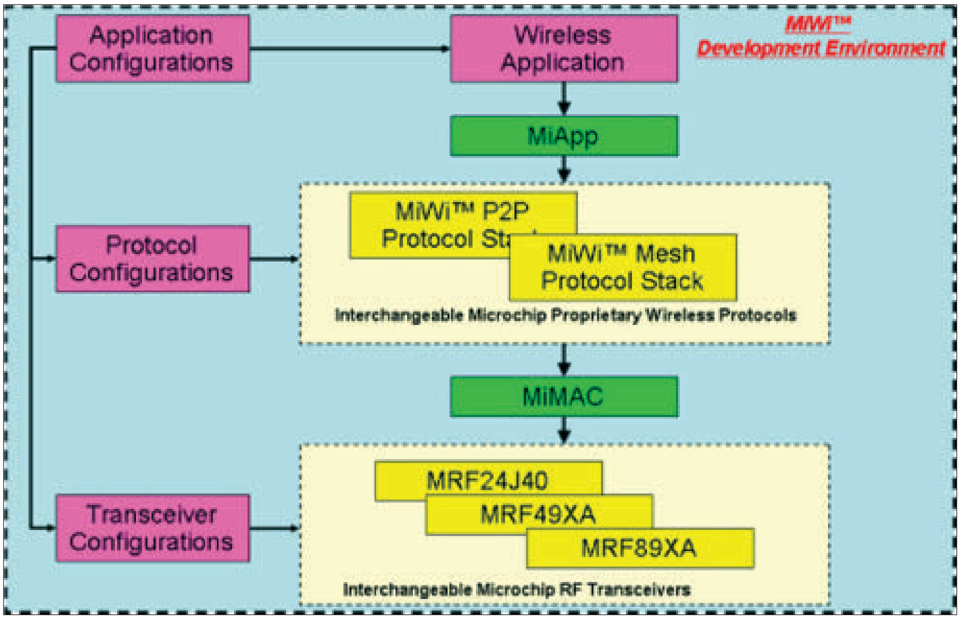
Microchip's new ZENA still captures ZigBee and MiWi traffic. However, the new ZENA you see in **Photo 4** is packaged as a plug-in USB unit and acts as the receiver for the Wireless Development Studio's 802.15.4 sniffer application.

I've set up a pair of PIC18F46J50-assisted MRF24J40MB radios on channel 11 running the MiWi P2P protocol. The node identified as ADDR 1 is programmed to attempt to connect to a peer. Following a successful connection, the ADDR 1 node will transmit "NUTS AND VOLTS ADDR 1." Node 2 — identified as ADDR 2 — is programmed to attempt to connect to a peer and enter receive mode. When a packet is received that begins with 0x01, ADDR 2 is to transmit "DESIGN CYCLE ADDR 2." Here's the transmit code for the transmitter node called ADDR 1:

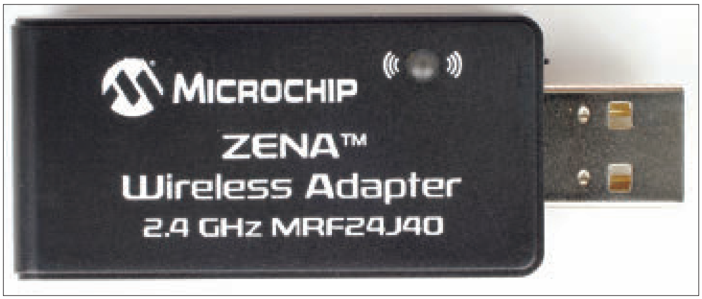
```
ROM char     DataPacket[] = {‘N’,’U’,’T’,’S’,’
‘,’A’,’N’,’D’,’ ‘,’V’,’O’,’L’,’T’,’S’,’
‘,’A’,’D’,’D’,’R’,’ ‘,’1’};

     MiApp_FlushTx(); //clear the transmit
                      //buffer
     MiApp_WriteData(0x01);   //write 0x01 to
                              //transmit buffer
     for(i = 0; i < sizeof(DataPacket); i++)
                      //copy DataPacket array to
                      //transmit buffer
     {
     MiApp_WriteData(DataPacket[i]);
     }

     MiApp_BroadcastPacket(FALSE);   //broadcast
                                     //packet with
                                     //no security
```


Application Configurations
Wireless Application
MiWi™ Development Environment
MiApp
MiWi™ P2P Protocol Stack
MiWi™ Mesh Protocol Stack
Protocol Configurations
Interchangeable Microchip Proprietary Wireless Protocols
MiMAC
MRF24J40
MRF49XA
MRF89XA
Transceiver Configurations
Interchangeable Microchip RF Transceivers

■ FIGURE 5. MiApp and MiMAC are integral to the interoperability of the various radios and MiWi protocols.


MICROCHIP
ZENA™
Wireless Adapter
2.4 GHz MRF24J40

■ PHOTO 4. Same interface with a new package and a new application suite.

Here's the ADDR 2 receiving node transmit code:

```
ROM char     DataPacket[] = {‘D’,’E’,’S’,
’I’,’G’,’N’,’ ‘,’C’,’Y’,’C’,’L’,’E’,’
‘,’A’,’D’,’D’,’R’,’ ‘,’2’};

     MiApp_FlushTx();        //clear the transmit
                             //buffer
     MiApp_WriteData(0x01);  //write 0x01 to
                             //transmit buffer
     for(i = 0; i < sizeof(DataPacket); i++)
                             //copy DataPacket
                             //array to transmit
                             //buffer
```

```
{
MiApp_WriteData(DataPacket[i]);
}

MiApp_BroadcastPacket(FALSE);
        //broadcast packet with no security
```

The 802.15.4 sniffer capture you see in **Screenshot 3** details the connection initialization. I powered up the receiver (ADDR 2) first, allowed it to attempt a connection, and let it settle into receive mode. Then, I fired up the transmit node (ADDR 1). ADDR 1 sent a P2P Connection Request just as ADDR 2 had done.

However, ADDR 2 was waiting for a connection request which, in this case, came from ADDR 1. ADDR 2 acknowledged the connection request, a peer-to-peer session was established, and ADDR 1 transmitted its message. ADDR 2 received the broadcast message and responded with its message. I figure you want to see the ADDR 2 receiver code:

```
if(MiApp_MessageAvailable())
         //if a good packet was received
{
  if(rxMessage.Payload[0] == 0x01)
         //check for 0x01 at start of data
  {
    MiApp_DiscardMessage();
         //clear the receive buffer
    MiApp_FlushTx();
         //clear the transmit buffer
    MiApp_WriteData(0x03);
         //write a 0x03 to the transmit
         //buffer
    for(i = 0; i < sizeof(DataPacket); i++)
         //copy DataPacketarray to transmit
         //buffer
    {
    MiApp_WriteData(DataPacket[i]);
    }

    MiApp_BroadcastPacket(FALSE);
         //transmit packet with no security
```

Just a walk in the park. The gravy is that both nodes now know each other's EUI-64 MAC address. Using the specific EUI-64 addresses, each radio node could switch over to Unicast mode and speak directly to each other.

The Wireless Development Studio sniffer application breaks down the 802.15.4-based MiWi P2P packet into bit fields. Each bit field yields information about the packet. This is a great way to learn about the mechanics of the 802.15.4 protocol and study the differences introduced by the MiWi P2P protocol.

LET'S SEE THAT AGAIN

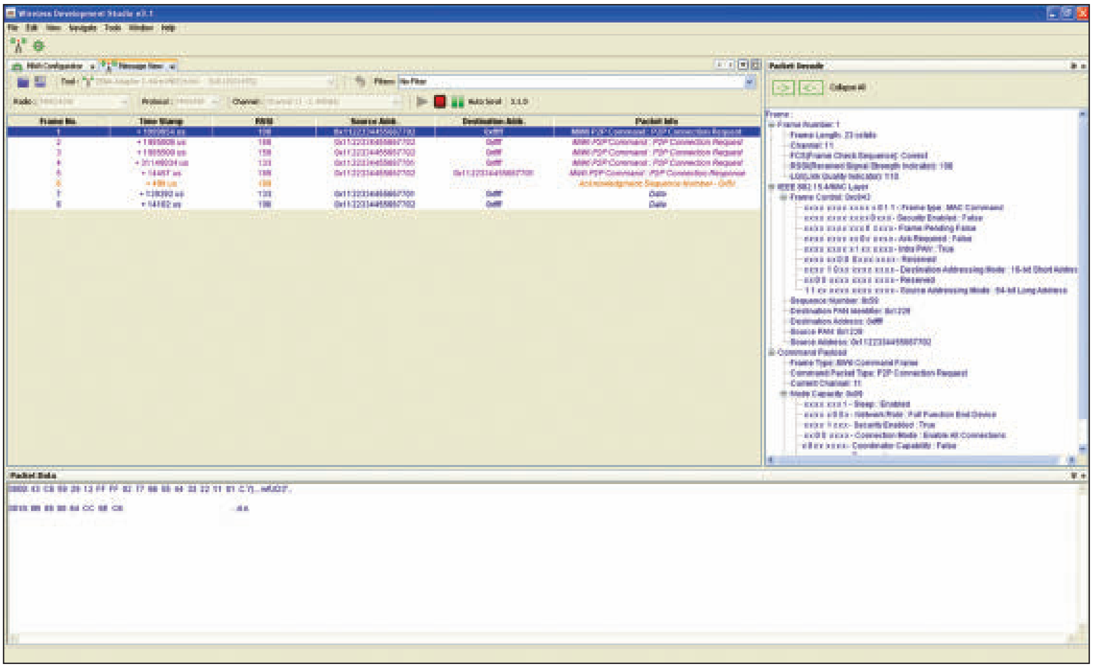
This time, I'll use the Exegin Q51 PANalyzer hardware you see in **Photo 5** in conjunction with the Wireshark network analyzer to grab P2P packets out of the air. The Exegin Q51 PANalyzer is designed to sniff ZigBee and 802.15.4 networks at remote sites.

The sniffed data can then be transferred via TCP/IP over the Internet to a Wireshark network analyzer running at the central monitoring station. The PANalyzer can interoperate with Wireshark to monitor the following protocols:

- 802.15.4
- ZigBee 2007
- ZigBee PRO
- ZigBee SCoP (ZIPT)
- 6LoWPAN
- Generic ZigBee Cluster Library

The Wireshark PAN protocol dissectors are open source. So, you can write your own dissector to sniff your unique profiles.

The PANalyzer contains an integral web server and a Telnet interface. Either interface can be used for network and PANalyzer configuration tasks. Network status and PANalyzer operational parameters can also be gleaned from these user interfaces. Access to the secure web server and



■ SCREENSHOT 3. The previous version of the ZENA capture application was graphical and a bit hard to follow. The new Wireless Development Studio sniffer application is chocked full of packet information that is easily flushed out and understood.

■ PHOTO 5. This tricky piece of 802.15.4 hardware can sniff remote 802.15.4 networks and send the sniffer captures home via the Internet.

STAT
NET
RF
Q51 ZigBee / 802.15.4 Transceiver

Telnet services is gained through an application called Gecko that ships with the PANalyzer.

Screenshot 3 is a PANalyzer capture of the connection and data transfer packets exchanged between our pair of MRF24J40MB nodes. Note that ADDR 1 and ADDR 2 are not real addresses.

The real hardware addresses can be found in the PANalyzer and ZENA sniffer captures. You can easily pick out the 64-bit addresses we assigned to each node in the **Screenshot 3** sniff. Everything from the Ethernet frame down to the 802.15.4 data is shown in the Wireshark/PANalyzer capture.

ONE MORE TIME

Alright already. We're out of paper. You will definitely see the ZENA and PANalyzer ZigBee/802.15.4 sniffers again. We'll have to figure out how to get that 802.15.4 PAN data to the face of my DROID. Until then, add the MRF24J40MB, 802.15.4, ZENA, and PANalyzer to your Design Cycle. **NV**

SOURCES

Microchip
MRF24J40MA
MRF24J40MB
ZENA
Wireless Development Studio
PIC18F46J50
MiWi
Microchip Application Libraries
www.microchip.com

Exegin Technologies
Exegin Q51 PANalyzer
Gecko
www.exegin.com

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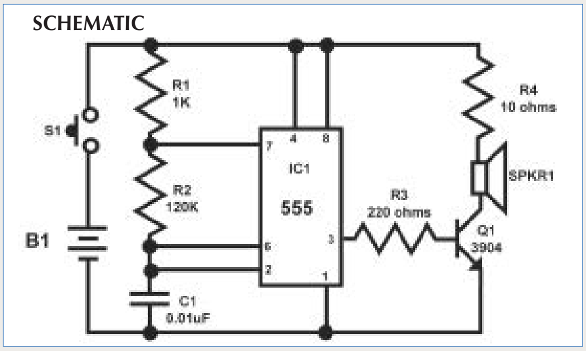
Build a Morse Code Oscillator

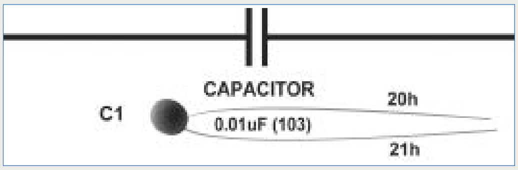
A kit for these experiments can be purchased from the *Nuts & Volts* Webstore at **www.nutsvolts.com** or call us at **800-783-4624**.

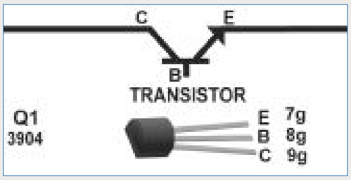
Try your hand at an "old school" communications method that is still practiced today.

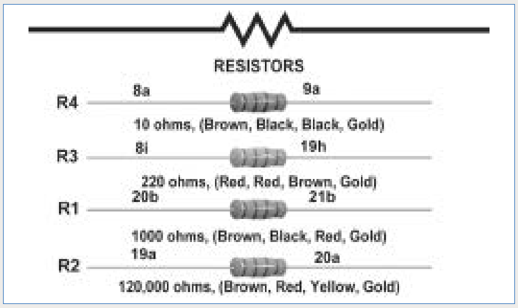
Build the Circuit. Using the schematic along with the pictorial diagram, place the components on a solderless breadboard as shown. Verify that your wiring is correct.

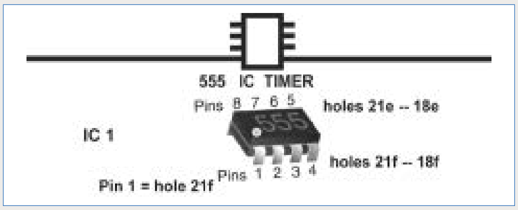
Do the Experiment. **Theory:** This project uses the 555 timer IC to emit pulses which are sent to a transistor to drive a speaker. R1, R2, and C1 control the duty cycle and therefore the frequency of the pulses coming from pin 3 of the 555 time. (The duty cycle is the percentage of time the output waveform is on compared to one complete cycle of on-off time. The formula for duty cycle is DC = Time On/ [time on + time off].) By interrupting the power to the circuit with switch S1, you can turn the sound on and off. **Procedure:** Connect a nine volt battery to the battery snap and press switch S1. You should hear a tone. (If you don't, recheck your wiring.) Use S1 to send Morse Code signals. If you wish, replace the pushbutton switch with a Morse Code key. Many ham radio operators still like to use Morse Code to communicate.

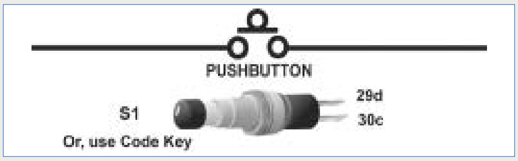

SCHEMATIC
S1
R1
1K
R2
120K
B1
C1
0.01uF
IC1
555
7
4
8
6
2
3
1
R3
220 ohms
R4
10 ohms
SPKR1
Q1
3904

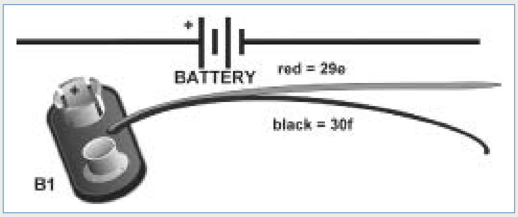

CAPACITOR
C1
0.01uF (103)
20h
21h

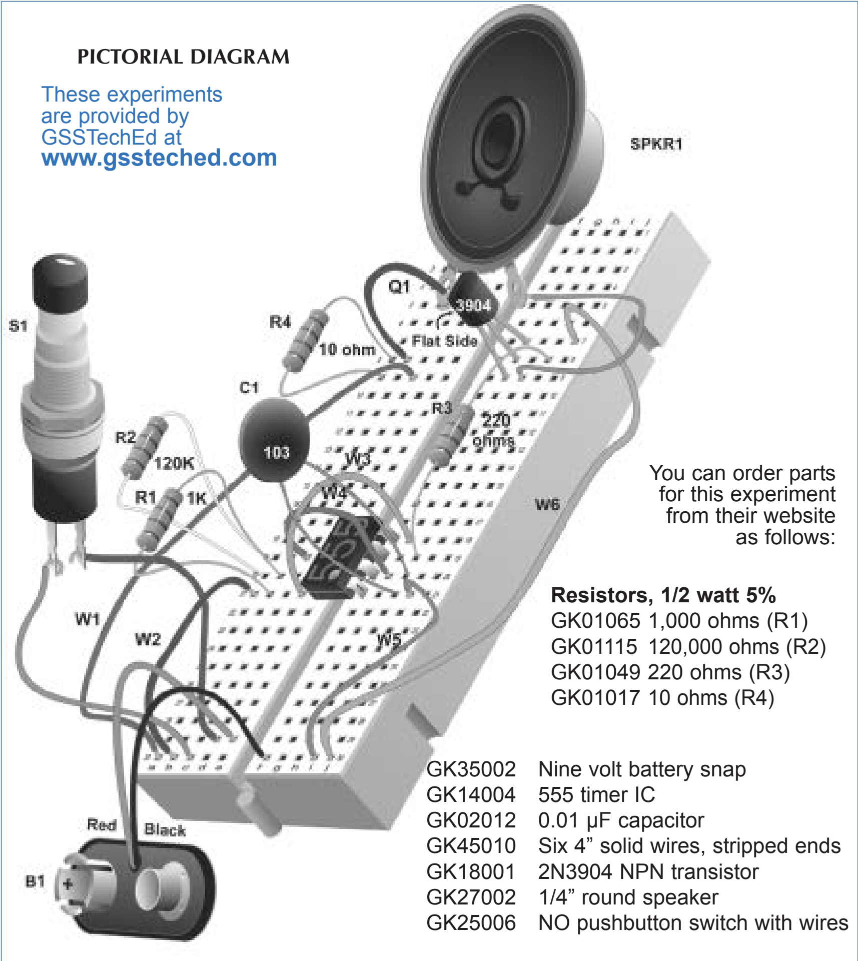

C
E
B
TRANSISTOR
Q1
3904
E 7g
B 8g
C 9g


RESISTORS
R4
8a
9a
10 ohms, (Brown, Black, Black, Gold)
R3
8i
19h
220 ohms, (Red, Red, Brown, Gold)
R1
20b
21b
1000 ohms, (Brown, Black, Red, Gold)
R2
19a
20a
120,000 ohms, (Brown, Red, Yellow, Gold)


555 IC TIMER
Pins 8 7 6 5
holes 21e -- 18e
IC 1
holes 21f -- 18f
Pins 1 2 3 4
Pin 1 = hole 21f


PUSHBUTTON
S1
29d
30c
Or, use Code Key


+
BATTERY
red = 29e
black = 30f
B1


PICTORIAL DIAGRAM
SPKR1
Q1
3904
Flat Side
S1
R4
10 ohm
C1
103
R3
220 ohms
R2
120K
R1
1K
W3
W4
W6
W1
W2
W5
Red
Black
B1
+

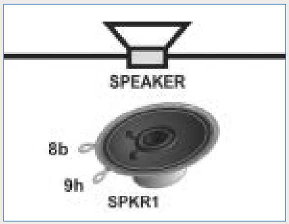
These experiments are provided by GSSTechEd at **www.gssteched.com**

You can order parts for this experiment from their website as follows:

Resistors, 1/2 watt 5%
GK01065 1,000 ohms (R1)
GK01115 120,000 ohms (R2)
GK01049 220 ohms (R3)
GK01017 10 ohms (R4)

GK35002	Nine volt battery snap
GK14004	555 timer IC
GK02012	0.01 µF capacitor
GK45010	Six 4" solid wires, stripped ends
GK18001	2N3904 NPN transistor
GK27002	1/4" round speaker
GK25006	NO pushbutton switch with wires

WIRES
W1 = 8c and 30a
W2 = 21a and 30b
W3 = 18g and 21d
W4 = 20g and 19d
W5 = 21i and 30i
W6 = 7j and 30j


SPEAKER
8b
9h
SPKR1

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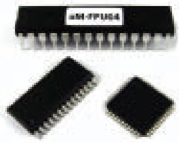

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Continued from page 33

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Cornell Dubilier Electronics
Web: **www.cde.com**

TECH FORUM
READER-TO-READER

>>> QUESTIONS

Solar LED Illumination

For several years, we have used a solar yellow LED deck lamp as a "Welcome Light" for our camper — the 12V "patio light" is just too bright, and ruins the moment.

I would like to have a simple NiMH/NiCad amber LED light that would be charged via solar, but also from the 12V onboard power when available. I also need an on/off switch for the LED.

#6121 **William Hogan**
West Lafayette, IN

VHF Receiver

Does anyone know of a VHF receiver that will tune in AM/SW signals after they've been frequency shifted up to the 216-302 MHz range? I would like to isolate the 500 kHz - 22 MHz band from a directional AM/SW antenna and use a local oscillator to raise them to 216-237.5 MHz. Then, I'd like to do the same for three other directional antennas to end up with four intermediate frequencies ranging from 216-302 MHz. I'm worried that a typical VHF tuner will only look for FM signals, of the wrong channel width, within the VHF band. These four new intermediate frequencies will now be high enough to make it through amplifiers (usually limited to 54-894 MHz) on our local cable system. I know that a local oscillator could be used at the receiver to bring them back down to their original range for use with a regular AM/SW radio, but I'm looking for an off-the-shelf solution without a hardware modified receiver. Can the "Uniden Home Patrol" or "GRC PSR-800" receivers have their Flash memory stored software modified to do this? The four separate intermediate frequencies will give the end user access to their choice of signals from four different directions. Something low cost, with an internal power supply (no wallwarts), and include Digital or SSB would be ideal. Thanks.

#6122 **Sam Grauman**
via email

Digital Technology?

I am a senior citizen plagued with hearing loss. I have been using hearing aids for about 30 years!! The vendors keep touting "digital" technology although none of them can explain how "digital" amplifiers work. I am familiar with analog amplifiers. Can someone give an explanation of this "digital" technology?

#6123 **William Porter**
Porter, OK

Compressor Starter

I am looking for a positive temperature coefficient motor starter for a compressor. Or, I need help using different parts such as a single pole contactor/relay for a hard start.

The part I want to replace has the following number: RF-6850-18, and consists of a PTC starter and an overload protector. Can I replace this with a hard starter contacter?

I can photocopy the schematics and email anyone who can help me.

#6124 **Michael Farley**
Cincinnati, OH

Generator Conversion

I'm considering converting an old car with manual steering to electric.

However, DC motors about 10 HP or more are expensive. I saw that the Northern Tool catalog has a 10 kw generator head with brushless technology (Item 165928). Is this a 13 HP brushless DC motor I could modify?

#6125 **Peter Vickers**
Hope Hull, AL

Thermostat Schematic

I need a simple schematic diagram which shows how the home thermostat controller is connected to the gas heater and to the air conditioning at the same time.

#6126 **Sam**
via email

FFT Audio Spectrum Analyzer

How can I implement FFT in microcontrollers so that I can do a frequency analysis of incoming audio signals that I have sampled through the A/D converter? I am not getting just where to start, though I know mathematical techniques of FFT. I want to deploy a cool audio spectrum analyzer for my audio system using matrix LEDs.

#6127 **Abhishek Kumar**
Meerut, Uttar Pradesh, India

DTMF Encoder

Where can I find a schematic or kit for a 16 button keypad encoder, without having to program a PIC? That's a regular telephone keypad plus A - D on the right side.

#6128 **Terry Arnall**
Hayward, CA

BJT Transistors

How do you measure BJT hybrid parameters HF, HI, HO, and HR?

#6129 **Jose Perez**
Guaynabo, PR

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Always use common sense and good judgment!

Send all questions and answers by email to **forum@nutsvolts.com**
*Check at **www.nutsvolts.com** for tips and info on submitting to the forum.*

>>> ANSWERS

### [#5121 - March 2012]
Display Advice

I need to build a high visibility display unit that consists of 15 1″ x 1-1/2″ display units. I've considered LEDs, Electrolum panels, and more. I cannot seem to find a display unit that can properly display true black and true white. I also need them to do at least 256 colors as well — nice, rich high resolution colors.

Is there such a thing? I believe I've seen them but am not sure where since I go to a lot of places displaying a lot of stuff.

Good luck finding a display that actually displays black. About the only thing that would come close is an "electronic ink" display as used on an Amazon Kindle.

Most displays — whether CRT, LED, incandescent, etc. — generate light. Black is the absence of light and with a CRT (picture tube) or LED display, the blackest black you're going to get is with the display off. It only seems "black" in the presence of all the contrasting colored light around it. Look at your TV with power off. That's its blackest black. Really! It doesn't seem that your "256 colors" is a good definition of "nice, rich, high-resolution colors." Your local paint store has more color chips than that by far and it's certainly not "high resolution."

Dean Huster
Harviell, MO

### [#5122 - March 2012]
LED Chaser

I need a schematic for an LED chaser for an atomic model my class is building. I will be using about eight to 16 LEDs. They need to be adjustable in cycling and speed. Could this circuit be expandable from, say, four to 40 LEDs?

By "LED chaser," I assume you mean a circuit that will light a series of LEDs one at a time in a sequential and cyclic progression. You can accomplish this using the MC14017 Decade Counter IC (download a datasheet from **www.onsemi.com**). A single MC14017 will provide 10 LED outputs. Figure 3 in the datasheet illustrates how to wire together several MC14017s (with the help of MC74HC08 AND gates) for obtaining more outputs (40 LEDs will require five MC14017s). You can drive the LEDs directly from the MC14017 outputs with a series resistor (~ 470 ohms). You'll also need an oscillator source, and an LM555 is the easiest way to do this. A convenient calculator for determining component values is available at **www.coolcircuit.com/tools/ne555_calculator/index.php**. You can use a potentiometer to make the oscillator frequency variable. If you make the frequency 10 Hz, for example, each LED will light for 0.1 seconds, and it will take one second to cycle through all 10 LEDs. All the components you will need can be ordered from Jameco (**www.jameco.com**). You can use the 74HC4017, 74HC08, and LM555, and any size/color LED you like. **Figure 1** is a basic schematic diagram to get started.

Bob Stewart
via email

### [#5124 - March 2012]
Bird Sound Circuit

About 40 years ago, I built a bird sound kit and put it in a Sucrets® metal box (same size as an Altoids® tin). I don't remember the name of the company, but the circuit was a blocking oscillator. I believe it had a miniature audio transformer; one side had a

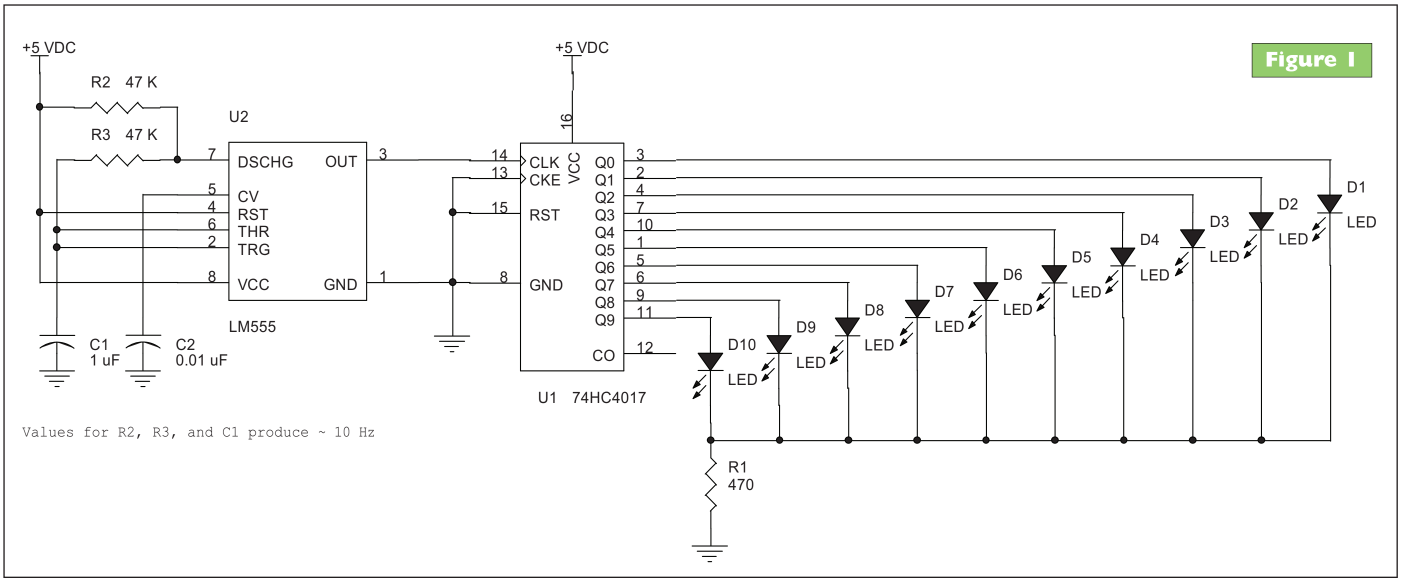


Figure 1

Values for R2, R3, and C1 produce ~ 10 Hz *center tap. I think it only had one transistor and ran on a single AA cell. I used a 1" speaker with a clear plastic diaphragm. You switched it on and it made a realistic repeating bird chirp. Better yet, if you lightly touched the speakercone, the sounds changed to other types of birds because of the change in reactance of the speaker. It was quite loud. Does anyone remember this and have a schematic?*

#1 I remember using a SN76488N 'sound generator' to build 'sound' circuits, such as train whistles, crowds cheering, birds chirping, and sirens, etc., for electronic games and other projects, but then I started to think about producing sounds as realistic as possible but in a less complicated way.

Here's a possible solution that you might want to consider.

I went to RadioShack and purchased a few of those handheld voice recorders [available at **www.tmart.com**] that allowed about a 10 to 15 second recording time. Pressing one button allowed recording, and pressing another button allowed audible playback. Removing a few screws, I simply wired a micro-switch in parallel with the playback switch and, when pressed, could instantly and repeatedly hear what I had recorded until I recorded over it with something else. I wired the output of the recorder to the input of a small audio amplifier [using an LM386 IC circuit] for a clear and loud output.

I wanted a crowd cheer each time a hit was made and a trumpet blare every time a man crossed home plate in my electronic baseball game. I was fortunate enough to have these realistic recorded sounds already programmed on my Technics keyboard. I simply pressed the record button, recorded the sounds, and then wired the recorders into the game. You can easily record real bird sounds for your project. You can store all bird calls into a memory chip and then play back, record, and use as needed.

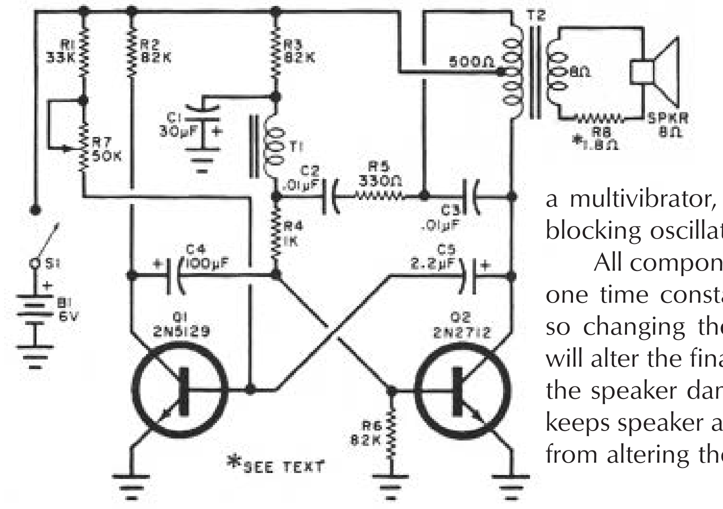
John Mastromoro

#2 The schematic and parts list shown below is from the three page article "The Solid-State Bird," by John Simonton, Jr. It appeared in *Popular Electronics* Spring 1973 "Electronics Experimenters Handbook." (*A scanned PDF of the entire article can be viewed or downloaded at the NV website.*)

The foil pattern measures 2 7/16" x 1-3/4", or 71 x 44 mm.

While searching, I also ran across two additional "bird sound" circuits: Dec. 1981 *Radio Electronics* "Electronic Bird Chirper" — four transistors, total 25 parts; and 1993 *Popular Electronics Electronics Handbook* "Hot Canaries" two LM324s, one transistor, two 1N914 diodes total 54 parts (no critical parts; parts count includes 9V battery, switch, and speaker).

Edwin Hampton
Mattoon, Il



This circuit is not as simple as it looks. Besides a multivibrator, there is also a blocking oscillator.

All components are part of one time constant or another, so changing the value of one will alter the final sounds. Note the speaker damping (R8) that keeps speaker acoustic loading from altering the oscillator.

PARTS LIST

Bl — 6 volt battery (four AA cells in series)
Cl — 30 µF, six volt electrolytic capacitor
C2,C3 — 0.01 µf disc capacitor
C4 — 100 µF 6V electrolytic capacitor
C5 — 2.2 µF 6V electrolytic capacitor
Ql — 2N5129 transistor
Q2 — 2N2712 transistor
Rl — 33,000 Ω, 1/2 watt resistor
R2, R3, R6 — 82,000 Ω, 1/2 watt resistor
R4 — 1,000 Ω, 1/2 watt resistor
R5 — 330 Ω, 1/2 watt resistor
R7 — 50,000 Ω trimmer PC pot
R8 — 1.8 Ω, 1/2 watt resistor
Sl — SPST slide or toggle switch
Tl — 10K:2K driver transformer (Lafayette TR-98, 99F61269, or similar)
T2 — 500Ω CT: eight ohm output transformer (Lafayette TR-116, 99F61293, or similar)
Misc. — Eight ohm speaker, plastic case, battery clips, wire solder, etc.

***Note** — At the time the article was written (1973), a PCB and complete kit were available from PAiA Electronics (**www.paia.com**). However, it appears they are no longer available. The foil pattern is included in the article scan on the NV website.*

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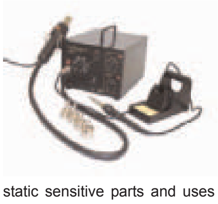

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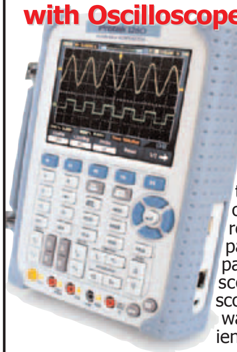

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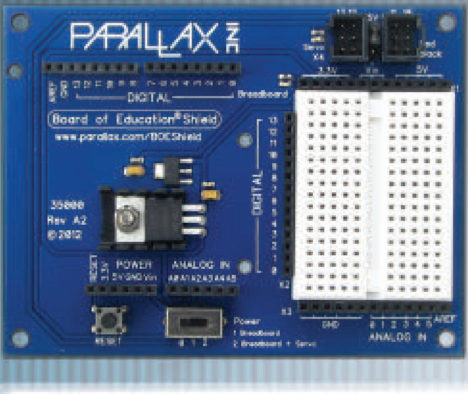

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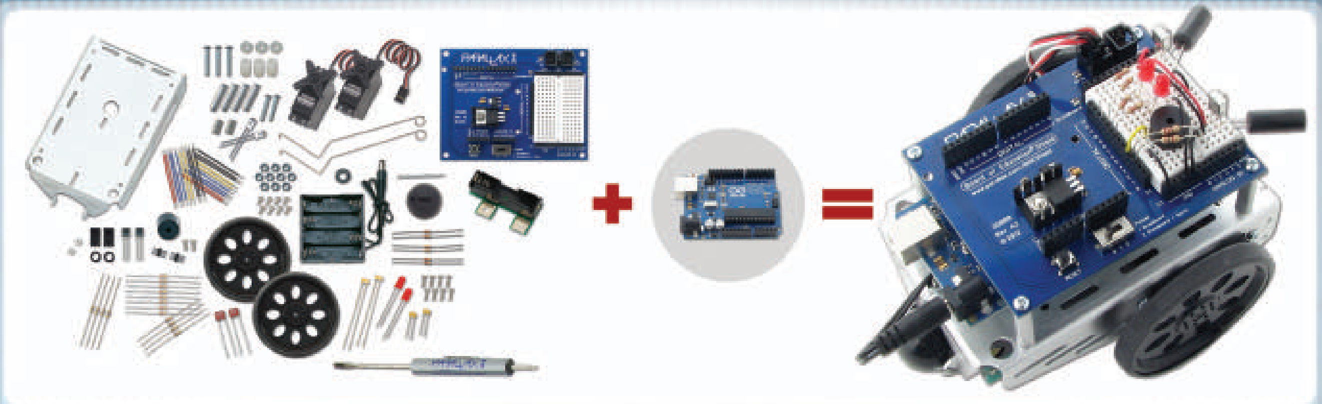

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